Problems in Longterm Forecasting and Planning: with reference to transport and energy

Thesis

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Problems in Longterm Forecasting and Planning: with reference to transport and energy

Thesis presented for the degree of
Doctor of Philosophy in Energy Research
at the Open University, May 1981

Authors no: HDD 6196
Date of submission: 1·5·81
Date of award: 10·8·81

ABSTRACT

PROBLEMS IN LONG TERM FORECASTING AND PLANNING: WITH REFERENCE TO TRANSPORT AND ENERGY

In this thesis I have set out my experiences of forecasting in the long term. (I have taken long term to be anything beyond 5 to 10 years). I have set forecasting in its context as a component of the planning process and have related the problems of forecasting to the ensuing problems in planning.

The main areas I have covered are Transport and Energy, in a UK context. However I have touched on other fields and I expect the conclusions I have drawn about forecasting and planning to apply to many fields.

The thesis is in two parts plus appendices.

In the first part I report three substantial pieces of research. They illustrate many of the problems associated with forecasting, and I examine possible solutions to these problems.

In the second part I describe how forecasts are made and some of the problems inherent in forecasting. I then examine why forecasts appear to be necessary in the planning/ policy making process. I conclude with the implications that my views on forecasting have for planning, and areas in which further research would be fruitful.

PREFACE

In this preface I give a brief account of how this thesis came about. It consists of a review of the research work I have done in the Energy Research Group over the last five years.

In October 1975, when I joined the group, I started a short study on goods vehicles. I was aiming to construct a vehicle population model akin to that for cars developed by Chapman and Mortimer (1975). The study led me to look at freight transport statistics and freight transport forecasts. While studying these I became dissatisfied with the attempts of Tulpule (1969), Tanner (1974) and Sharp (1973) to use a tonne-kilometer/ gross domestic product relationship for making forecasts. I began to develop ideas on other ways in which freight transport forecasts could be made. I was also involved with the group electricity system study (Energy Research Group 1976).

In 1976 I became involved in the Future Transport Fuels study (Chapman et al 1976). Some of my contribution to this study included identifying sources of data and working out how to build up an energy supply and demand scenario into which to fit the study of transport energy demand.

The Future Transport Fuels work led to a conference (Baker and Charlesworth 1977a) and several papers (Baker and Charlesworth 1977b, 1978 and Charlesworth and Baker 1978) plus a further study of vehicle refuelling infrastructures (see below).

Overlapping with this was work on a submission to the Science Research Council for continuation of the group's input-output (I.O.) study with which I was peripherally associated. My contributions to the preparation of the submission were suggestions on how the physical I.O. model could be dynamicised and suggestions on how transport could be incorporated. At this time I wrote 4 working papers (Baker 1977a,b,c and Mellish and Baker 1977). The first two of these related to my interest in freight transport and were to have been the basis of the work for my thesis which was going to be on "the determinants of freight transport". (Chapter 1 of this thesis is based on these two papers.)

Later in the year (1977) I also became involved in reworking a paper which had been writen by another member of the group (Martin Mellish who subsequently changed his name to Vimukta). The paper which was on "Integrating Wavepower into the Electricity System" (Vimukta et al 1978) had been accepted for an international conference, but several changes had been called for. My contribution to the revised paper was major since the computer programmes (upon which the paper was based) were very poorly documented and required substantial revision.

The groups work on input-output led to an approach to the Transport and Road Research Laboratory to see if we could do some work on providing a disaggregation of the transport entries (between passenger and freight) in the I.O. tables, for both 1968 and 1974. At that time the Central Statistical Office were in the process of constructing the 1974 tables. I was involved in the setting up of the resultant research contract and was responsible for most of the work on the study. Due to the amount of work involved it was only possible to obtain results for 1974 (see Chapter 3 of this thesis and Baker 1979a,b and 1980).

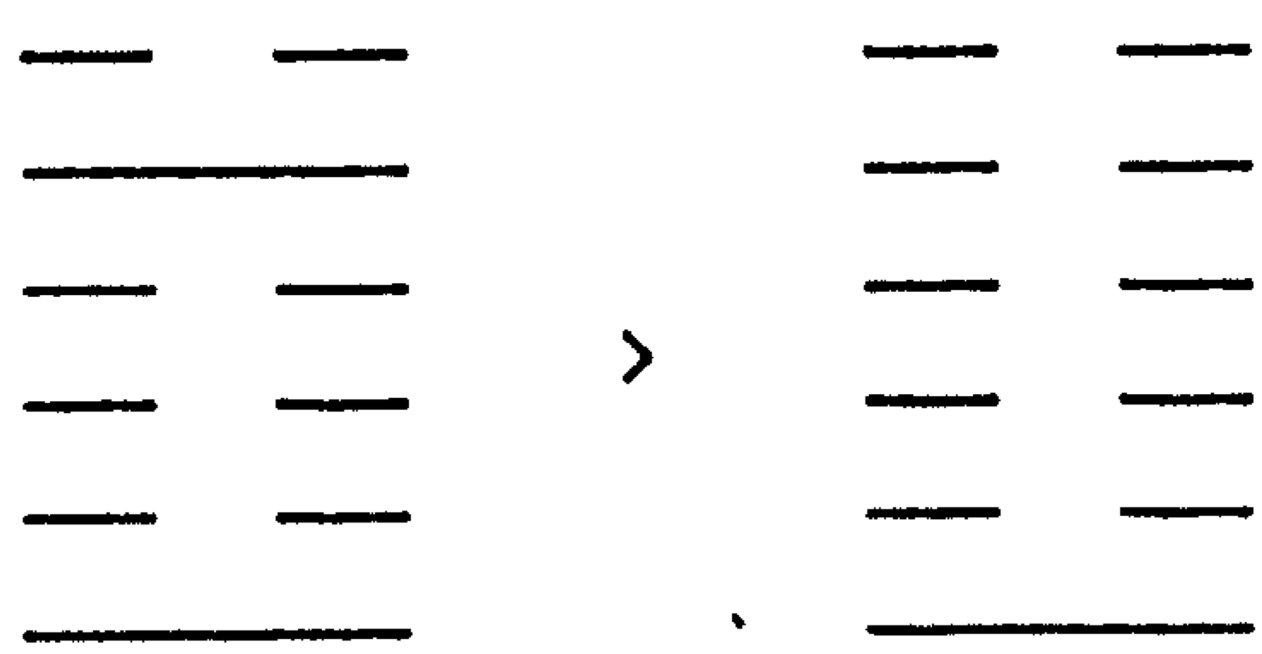
During this period I was also involved in a continuation of the Future Transport Fuels study which involved looking at Road Vehicle Refuelling Infrastructures. (I have completely reworked this study and it appears as Chapter 2 of this thesis.)

During 1978 and 1979 I was heavily involved in student politics. This involvement ceased during September 1979 which left me with one year in which to complete my thesis work. Through out the period 1976 to 1979 I had intended that my thesis should be on freight transport. However on reviewing the work involved in what I had originally intended to do (Baker 1977a and b) it became apparent that there was <u>at least</u> a years work to do before any writing up could start. I also came to realise that in the previous 4 years I had done a lot of research, all original and much of it on my own and largely unsupervised. I decided that I should write up work I had already done, rather than embark on any new work.

Although not intentional there was a common thread through all of the work I had done. This was about the problems involved in making forecasts. It is this thread which provides the theme of the thesis and to illustrate some of the points made in the thesis I have used three pieces of my previous work as case studies. These are on freight transport, vehicle refuelling infrastructures and the transport input-output study.

I would like to take this opportunity to thank the other members of the Energy Research Group for providing a very stimulating atmosphere to work in. In particular I would like to thank Jake for all his help and encouragement in this work and in life.

Thank you Jake.



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INTRODUCTION

When I came to the Energy Research Group (ERG) in 1975, I thought that forecasting problems were in large part due to insufficient attention being paid to detail. The models used in forecasting exercises tended to be very aggregated and cover very small systems. I had the idea that forecasting problems could be overcome by paying more attention to this detail.

My ideas, on what the forecasting problems were, were not very clear. However I was aware that serious mistakes had been made in the past. For example during the 1960's and early 1970's the electricity industry in Great Britain had made substantial over estimates of electricity demand as we (in ERG) found in our Electricity Industry study (Energy Research Group 1976). The conventional explanations given for the electricity industries past forecasting errors were:

(a) poor economic performance,

(b) cheap natural gas,

(c) the price of the industries fuels (coal and oil) had been forced up by the miners and Arabs.

However we concluded that these reasons did not adequately explain the errors and that there were additional reasons which were:

(d) an asymmetry in the penalties incurred by the industry between making under and over estimates of demand which lead to a tendency to make overestimates,

(e) the development of an exponential mentality which assumed that growth was inevitable,

(f) tying demand estimates to GDP then over estimating economic performance without regard to how the electricity could be used or by whom.

The first time that I personally found previous forecasting exercises inadequate was in a short study I did on goods vehicles. I was aiming to produce a population model of goods vehicles along the same lines as that developed by Chapman and Mortimer (1975). Basically they used their model to examine car registration data in terms of birth rates (new car registrations), death rates (scraping) and age. In their model there was an underlying assumption that demand for cars (the saturation level) is related to the countries population (which had been fairly static over the period they were investigating, 1950 to 1975). With the model they estimated a saturation level based upon the point at which the rate of change in the car population went through a peak.

However when applying their model to goods vehicles I encounterd several problems, the most important of which was that there is no obvious static or saturation level of demand for goods vehicles (or road freight transport). There had also been a change in the relative distribution of goods vehicles by size. Finally I found a discontinuity in goods vehicle registration figures caused by the transfer of the Post Office from a government department to a public corporation in 1969.

The increasing demand for road freight transport suggested to me that there was a need for a model of goods transport demand. Those which had been developed for the United Kingdom by Tulpule (1969), Tanner (1974) and Sharp (1973) appeared to me to be totally inadequate. This led me into an investigation of freight transport statistics as a basis for a disaggregated freight transport forecasting model.

As a result of the work I did on freight transport statistics and subsequent work on future transport fuels and the compilation of data on transport for the Central Statistical Office's 1974 Input-Output tables, I have come to a deeper understanding of the problems inherent in forecasting and planning.

This thesis is in two parts. The first part starts with three chapters in which I describe the work I have done on freight transport, future transport fuels, and the 1974 input-output tables. In each of these chapters I draw out the problems which I encountered while trying to make improvements to the forecasting process. The first part concludes with a chapter in which I review the lessons I have learnt about forecasting.

In the second part I look at the forecasting process in detail and examine the problems involved. I then give a general description of the planning process and look at why forecasting appears to be necessary. Finally I examine the implications the forecasting problems have for planning.

1. FREIGHT TRANSPORT STATISTICS

1.1 Introduction

In this chapter I give details of the work which I did on gaining an understanding of freight transport. I go on to outline further work which could be done in this field, and end with the lessons I learnt about data, modelling and forecasting.

My aim in doing this work on freight transport was to try and get sufficient disaggregation of data to be able to get reliable explanations of time trends in freight transport.

In this chapter freight transport is taken as the movement of goods by all modes except the movement of fluids by pipe for which, in general, no other method is used. This excludes gas, water and sewage, but includes petroleum movement by pipeline.

The chapter starts with a brief review of some other attempts at understanding or modelling freight transport in Britain. In it I then go on to look at a simple model, which I found to be inadequate to describe the changes which have occured over the past 25 years. A more detailed model which should help to explain the changes is described and the extra data required for this model is outlined. Associated with this chapter are three appendices. The first gives details of the sources of data which are available, the second describes the different commodity groupings used in the sources and the third describes a method for determining net physical production based on the use of input-output tables.

1.2 Review of some past work

The principal physical measure of freight transport output is tonne kilometers of freight moved. It is roughly comparable between different modes of transport and most costs vary in proportion to it. Consequently several different methods have been developed to project or forecast the total demand for freight transport in Great Britain in terms of tonne-km by all modes. However, earlier work was of a rather superficial nature due to the lack of any theoretical models to explain or clarify the underlying trends.

In one method used for forecasting freight transport demand, the quantity of freight transport is assumed to be proportional to the total quantity of goods produced. GDP is used as a proxy for the total national output, and so demand as measured in tonne-km has been correlated with GDP (Tulpule 1969, Tanner 1974, Sharp 1973). For example Tanner (1974) found a constant ratio, between 4.0 and 4.3 tonne-km per pound of GDP, over several years. However he found that there had recently been a fall from the pre 1970 ratio and for his forecasts he substituted an increase in tonne-km of 2/3 of that of GDP in place of a 1 for 1 correspondence.

Another method used for projecting demand has been to look at the number of tonnes lifted and the average distance over which they have been moved. For example in the first appendix to the 1976 Transport Consultation Document (Department of the Environment 1976) the number of tonnes moved was noted to have been roughly constant for the previous 10 years (1965 to 1974, at about 1.9 thousand million tonnes) and all the increase in tonne-km moved could be attributed to an increase in the average distance over which freight was moved (64 to 77 km). This does not seem to be compatible with a causal relationship with GDP which suggests that an increase in freight transport should be explained by an increasing quantity of goods lifted.

An alternative approach was investigated by Brown and Maultby (1974). They developed a model based upon assigning a transport intensity to each element of an input-output table. The model then requires a projection of the absorption table for the year in question to obtain the quantities of each commodity to be transported in that year. However, as official input-output forecasts are unlikely to be made, further development of this method was postponed. Instead they developed a model which explains the volume of freight transport (in tonne-km) in terms of the movement of activity level indicators for the seven industries which account for 90% of freight transport. One critisicism which can be made of both of Brown and Maultby's methods is that they do not take account of possible changes in the average distance over which each commodity is moved.

Another possible method of forecasting the volume of freight transport is the construction of an inter-regional commodity flow model, based upon the concepts of urban traffic models. First the volume of each commodity generated by and attracted to each of many zones would be forecast. Then a forecast of the distribution of each commodity between its origins and destinations would be made. O'Sullivan (1972) used details from the 1962 Survey of Road Goods Transport (Ministry of Tranport 1964-66) which included details of the movement of 34 commodities between 107 areas in Britain augmented by similar data from a survey carried out by British Rail for 1964. He found that starting from the known volumes of each commodity originating in and destined to each area a linear programing solution describes the distribution of commodity flows well. He also cited other work which has been done on "establishing estimating equations relating tonnages of commodities generated and attracted to employment in various industries and to residential population" (O'Sullivan 1970, Chisholm 1970).

A possible development of the inter-regional commodity flow model would be to construct a multi-region input-output model. The minimum requirement would probably be of the order of 10 regions and 10 industries/ commodities. However apart from the previously mentioned road freight survey in 1962 and rail survey in 1964 there are not sufficient freight statistics to calibrate such a model. Neither are there details of the regions' economies in sufficient detail to build up the individual regional input-output characteristics. One of the problems which would be encountered when using such a model for forecasting purposes would be forecasting the growth or decline of all sectors in all regions. However the work of Chisholm and O'Sullivan is directed to this end. In the conclusion to their book Freight Flows and Spatial Aspects of the British Economy (Chisholm and O'Sullivan 1973) they say that one of the areas which needs further research is the "stability or otherwise of parameters over time".

Although the available historical freight transport data is not sufficiently detailed to give much spatial disaggregation it can yield time series of such parameters as the average length of move for various commodities. It is towards an aspatial model of freight transport that this study was directed.

1.3 Preliminary analysis

Over the period 1952 to 1975 there was a considerable growth in both the tonnage of freight lifted per year and the total of tonne kilometers of freight moved per year in Great Britain. The quantities lifted and moved are illustrated in Figures 1.1 and 1.2 respectively.
(The sources of data used for these and all other figures and tables are given in Appendix 1). Although there was considerable growth in the tonne-km of freight moved per year over the whole period it was due to different causes. Over the period 1952 to about 1965 the growth was largely due to an increase in the number of tonnes lifted per year. However in the period 1965 to 1975 the growth was mainly due to an increase in the average distance over which freight was moved. The average distance can be found by dividing the tonne-km moved per year by the tonnes lifted per year, for each year. The results of doing this are shown in Figure 1.3.

To get a further understanding of the number of tonnes lifted per year it is useful to consider the amount of material which is flowing around the country. A simple representation of the system within which the vast majority of freight transport occurs is shown in Figure 1.4.

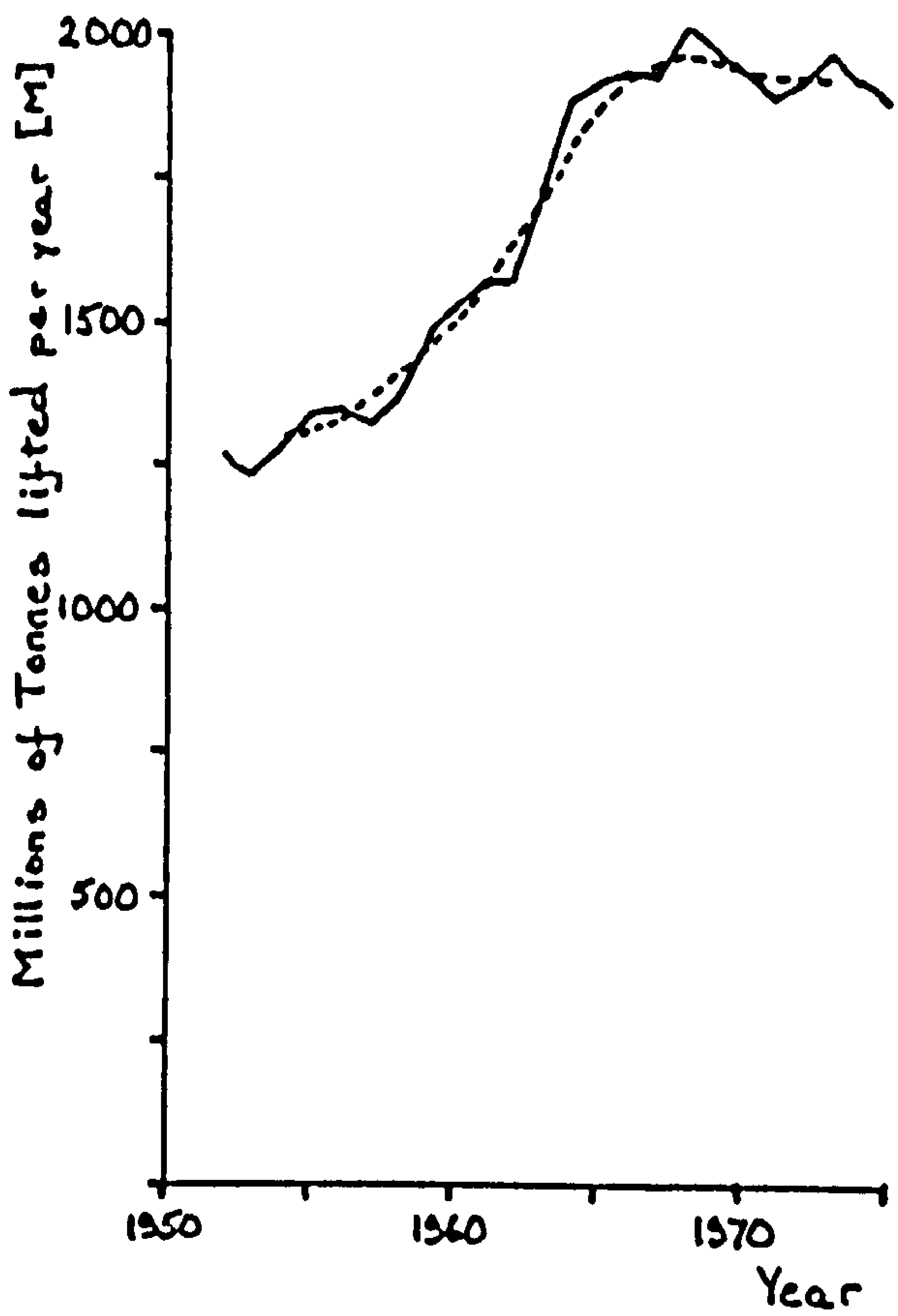


Figure 1.1 Tonnes lifted per year in GB by all modes

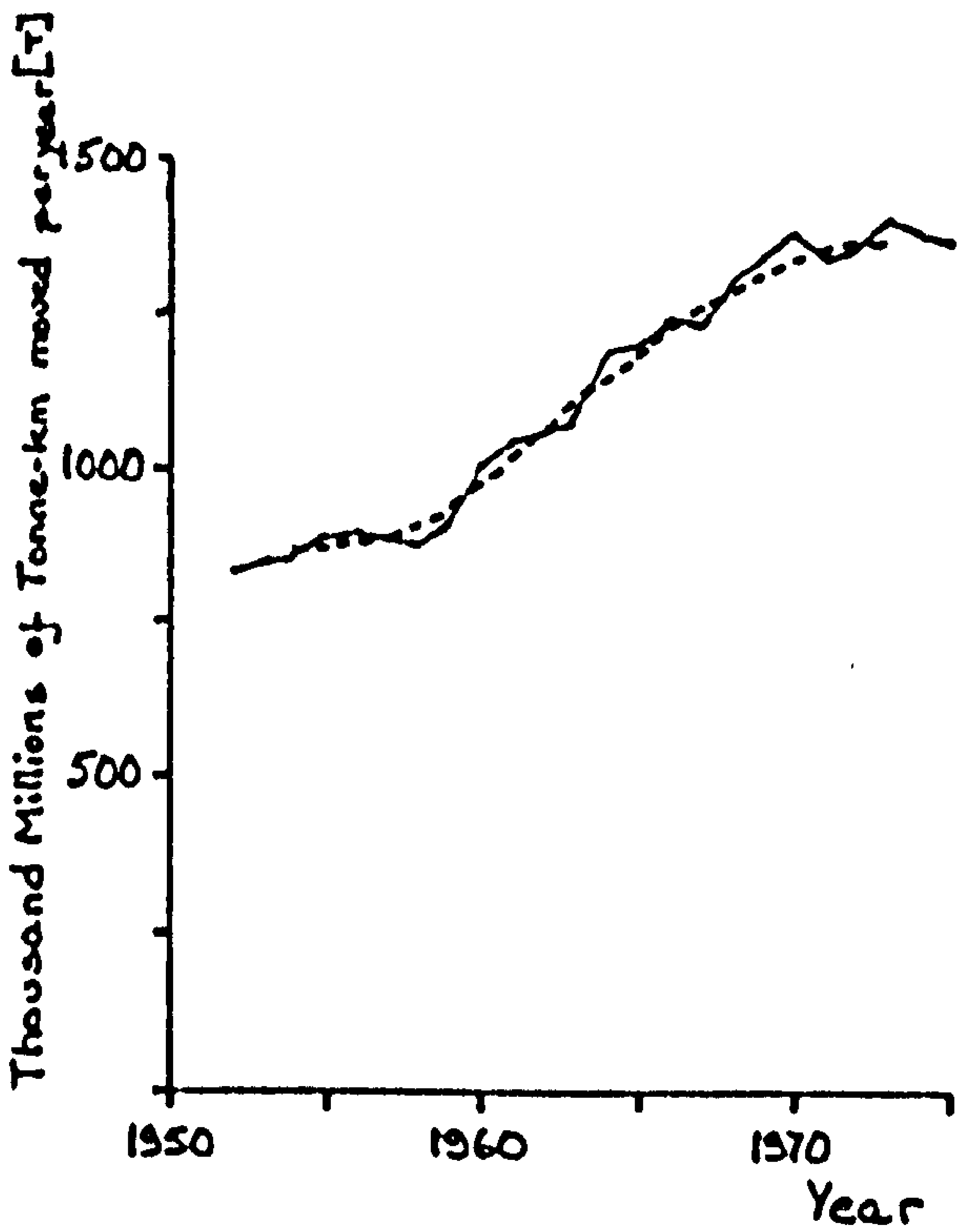


Figure 1.2 Tonne-km moved per year in GB by all modes

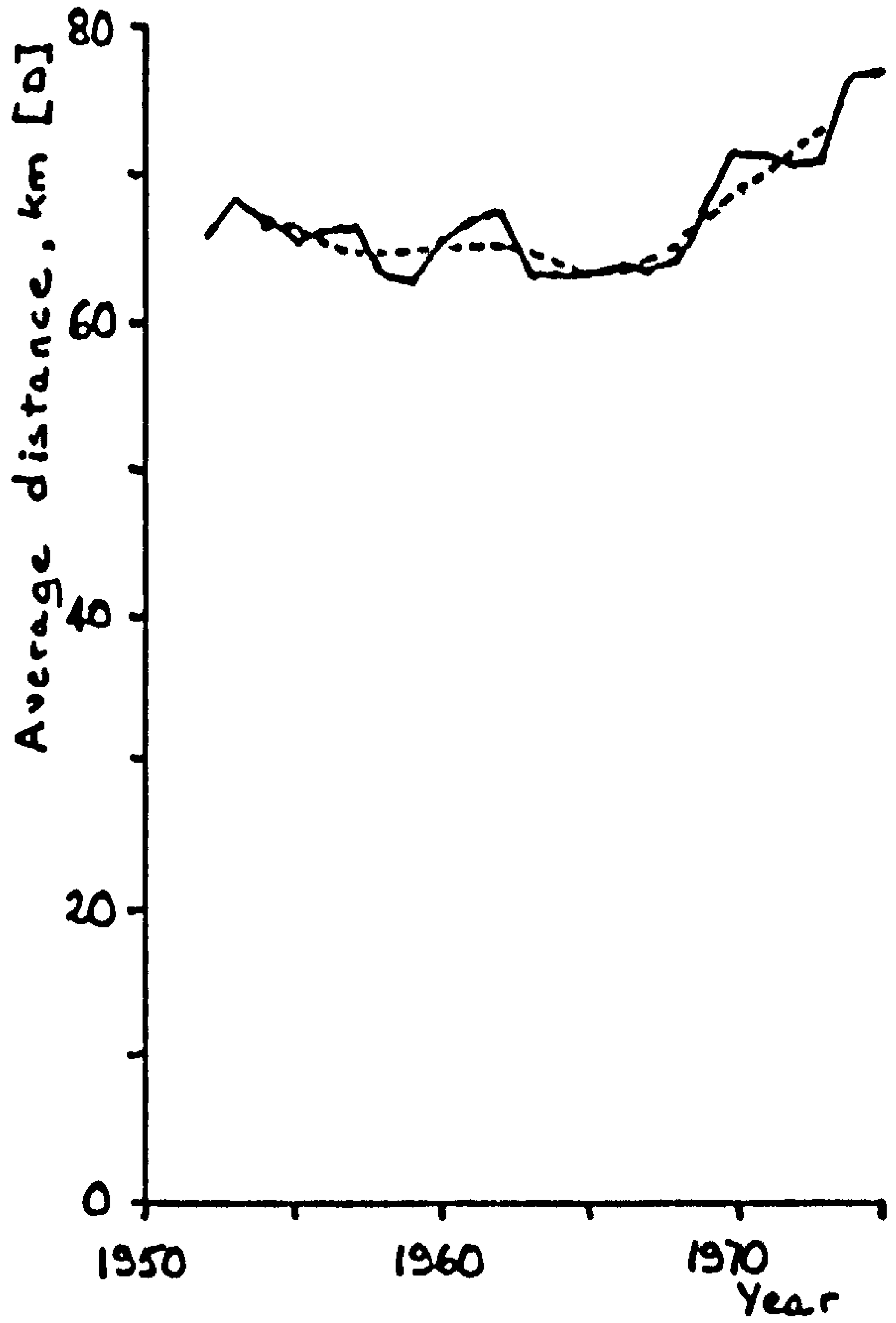
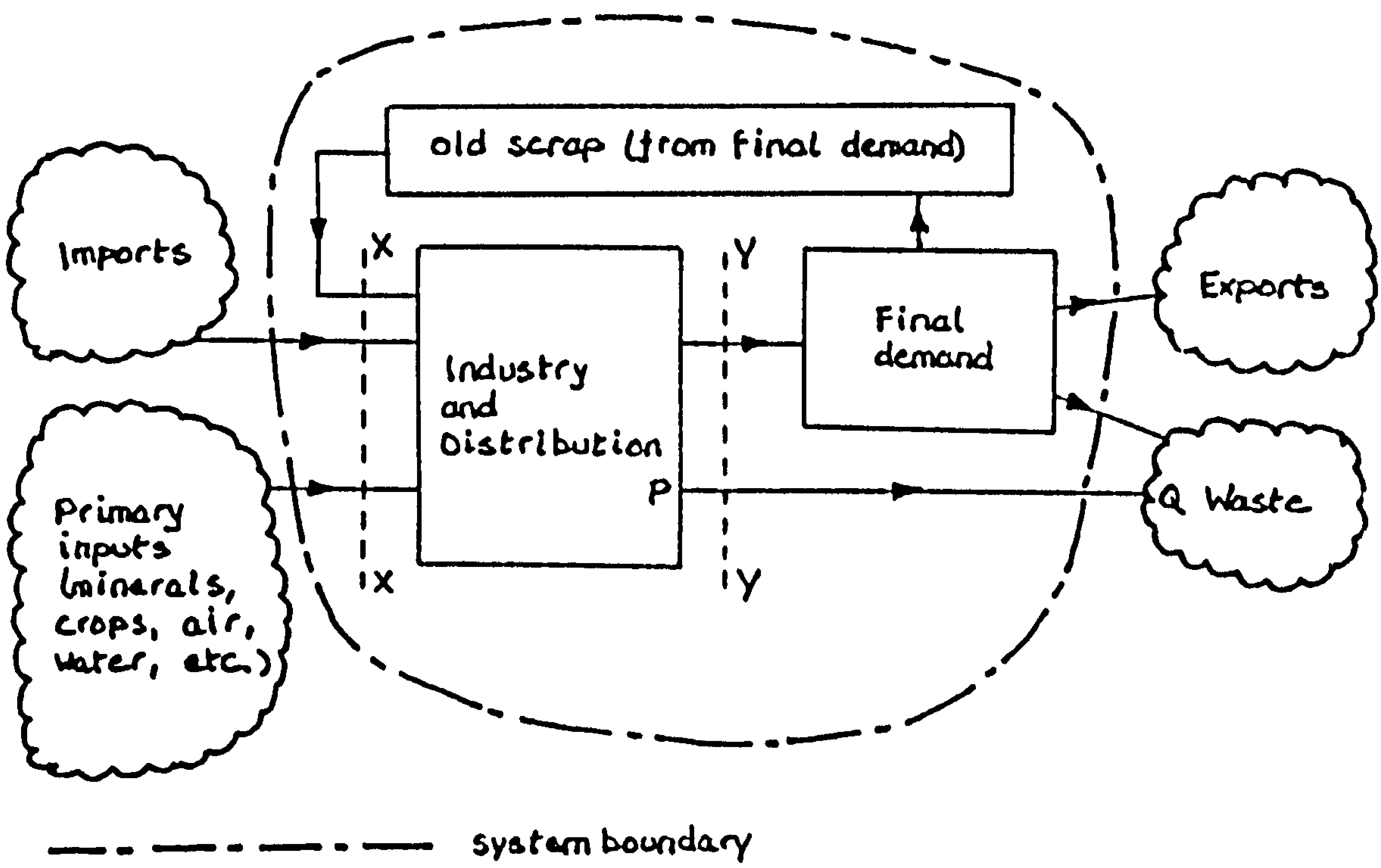


Figure 1.3 Average distance overwhich Goods are moved in GB by all modes



note: The vast majority of freight transport occurs within the Industry and Distribution systems. The flows shown in the above system are not necessarily associated with freight movements but represent the points at which commodities enter or leave "Industry and Distribution", and "Final Demand". Of particular importance is "PQ" which represents industries wastes which are returned to the natural environment. Many of these, such as carbon dioxide and water born effluents, are not transported.

Figure 1.4 Industrial and Distribution system within which freight transport operates

The system boundry for Imports and Exports are the docks (for convenience the point at which the goods pass through Customs as this is well documented). The system boundary for primary inputs (such as minerals and crops produced in Great Britain, and water and gases taken from the air which are retained in products) and waste is at the point at which they are removed from or returned to the natural environment. (In the case of primary inputs it is more convenient to take the point at which the production of the respective industry is documented).

In a system in equilibrium, the mass flow over the lines XX and YY would be equal, and we could consider this to be the mass flow through the

Industrial and Distribution system. As the mass flow over XX is fairly well documented we can take this as the mass flow through the system. Since the rate of growth in this mass flow has been of the order of 2.5% per year (for the period 1961-75) the mass flow at XX will be only slightly different from that at YY. Consequently using the flow at XX rather than any other measure of the flow through the system will have a negligible effect on the analysis.

The cumulation of all imports and primary inputs (but excluding retained air and water) over the period 1961 to 1973 is shown in Figure 1.5.

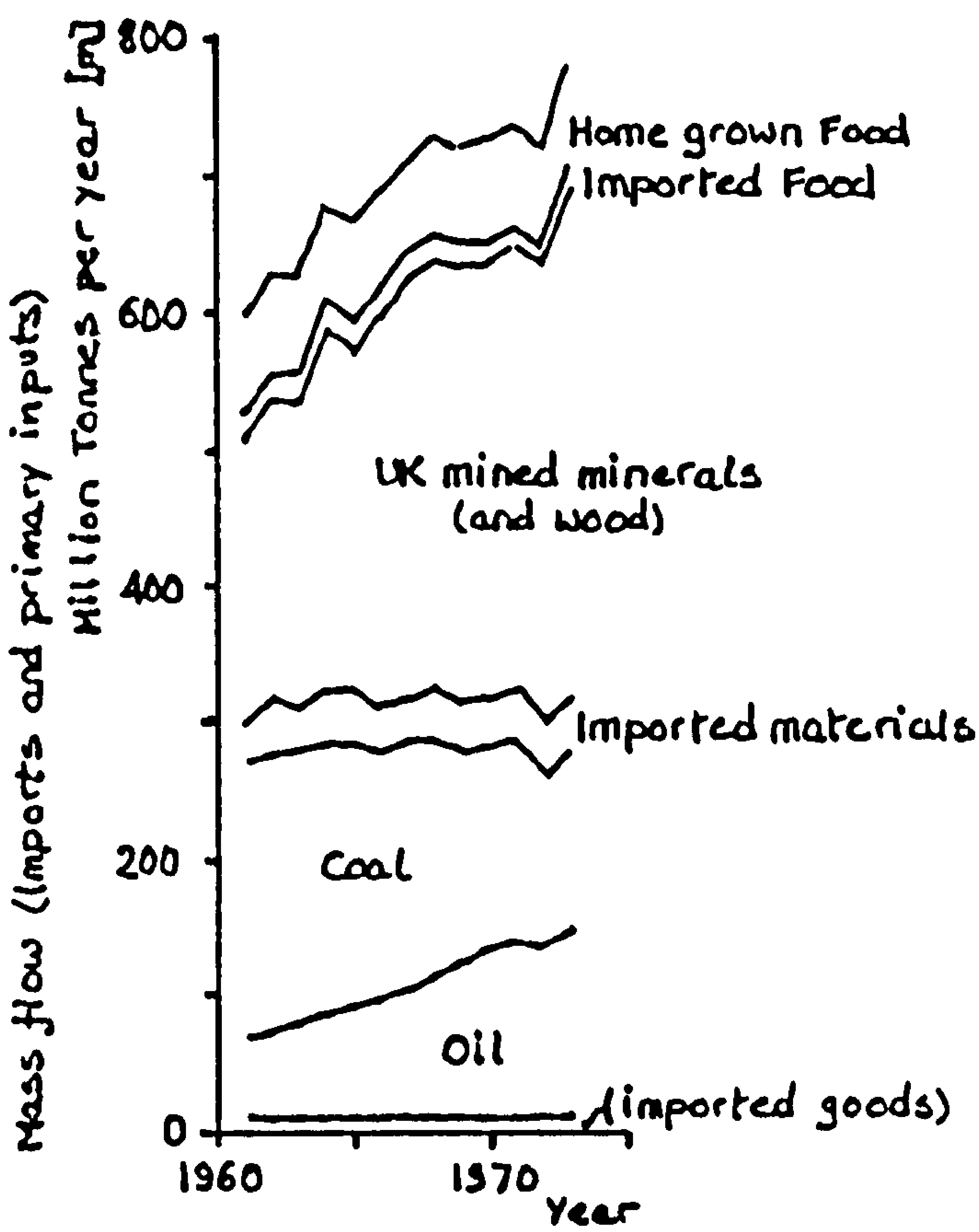


Figure 1.5 Mass flow into the UK industrial and distribution system

It is interesting to note that apart from a switch from coal to oil all other categories have remained essentially static with the exception of UK mined minerals. In this preliminary analysis old scrap was not documented due to lack of readily available data. Also the quantities in Figure 1.5 refer to the UK rather than GB because these figures are more readily available [1].

The average number of moves for all commodities between entering and leaving the Industrial and Distribution system can be found by dividing the number of tonnes lifted per year by the mass flow through the system. The approximate average number of moves over the period 1961 to 1973 are shown in Figure 1.6.

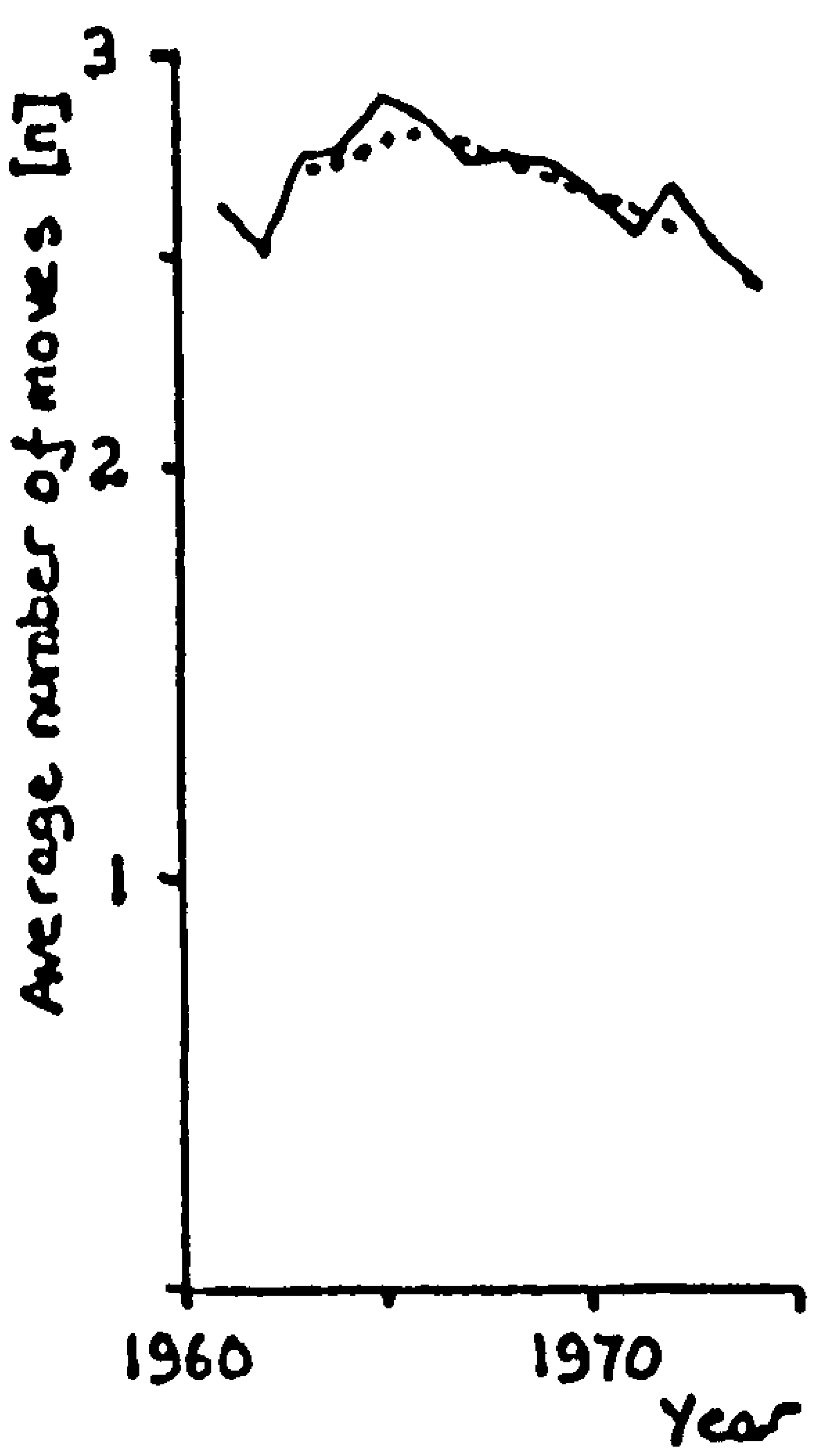


Figure 1.6 Average number of moves

The reasons for the numbers being approximate were that the mass flow used for the UK did not include any packaging and was not complete, whereas the freight lifted per year was for GB and included the weight of packaging.

The relationship between tonnes per year, tonne-km per year and distance moved can be expresses mathematically.

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[1] Since completing this preliminary analysis I have found that the imports listed in the Annual Abstract of Statistics (Central Statistical Office annual a) are not complete. See Appendix 1 for further details.

Let

M = sum of all tonnes lifted per year

T = sum of all tonne-km moved per year

Then the average distance moved

$$D = T/M$$

This can also be expressed as

$$T = MD = \sum_{\substack{\text{all}\\ \text{goods}\\ \text{movements}}} \text{tonnes lifted per year} * \text{distance moved}$$

The relationship between mass flow, freight lifted per year and average number of moves can also be expressed mathematically.

Let

m = mass flow through the Industrial and Distribution system (equal to flow across XX or YY in Figure 1.4)

n = average number of moves

Then

$$n = M/m$$

1.4 Further analysis

Unfortunately the preceding analysis obscures much of the detail of what was happening. More detail can be obtained by considering the movement of individual commodities. This involves a shift from looking at the inputs to the industrial system to looking at the output of individual industries.

Figures 1.7 and 1.8 show the cumulative number of tonne-km moved per year, and of tonnes lifted per year respectively, of eight commodities for the years 1962, 1967/68 and 1974.

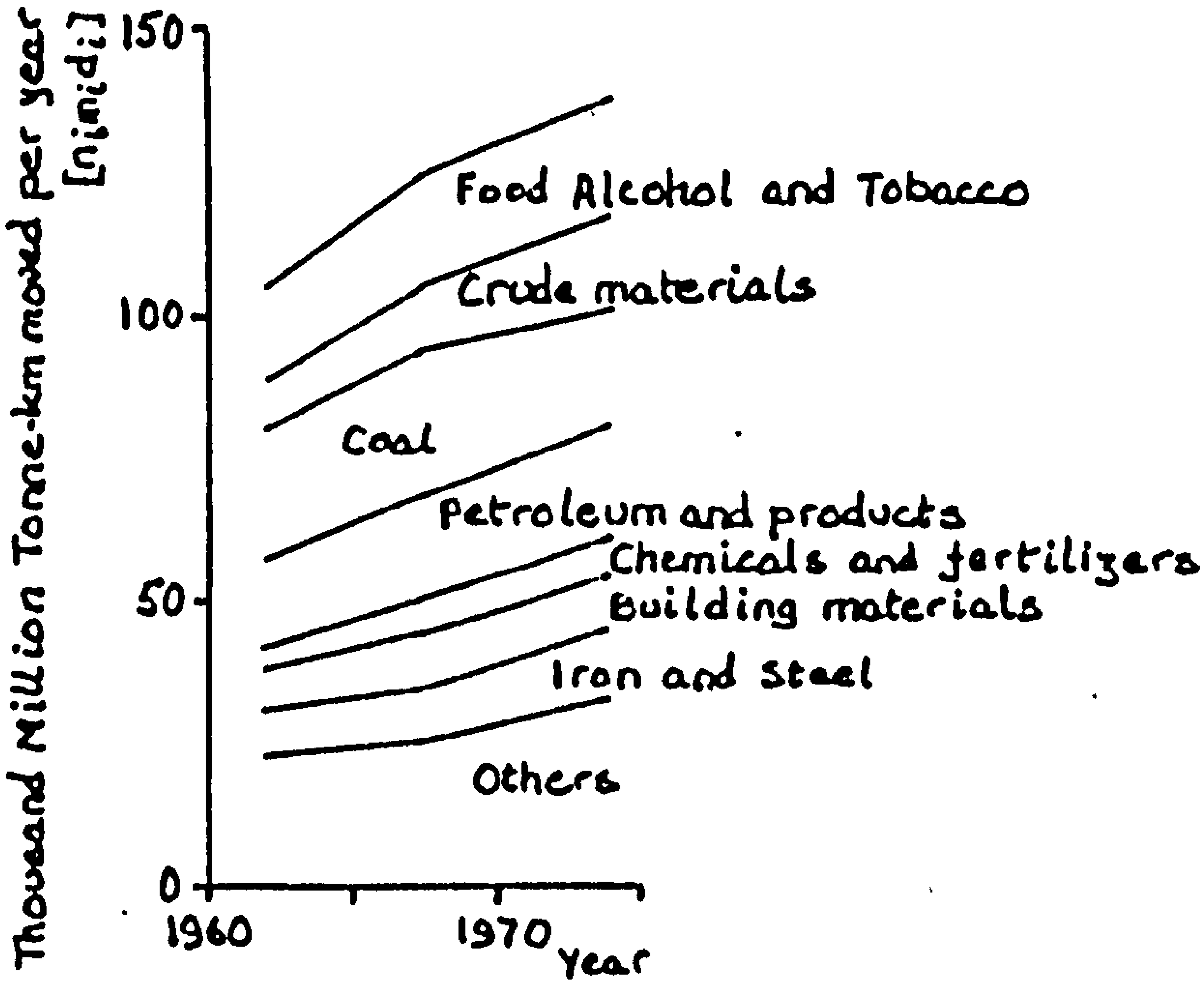

Figure 1.7 Tonne-km moved per year in GB by all modes: by commodity

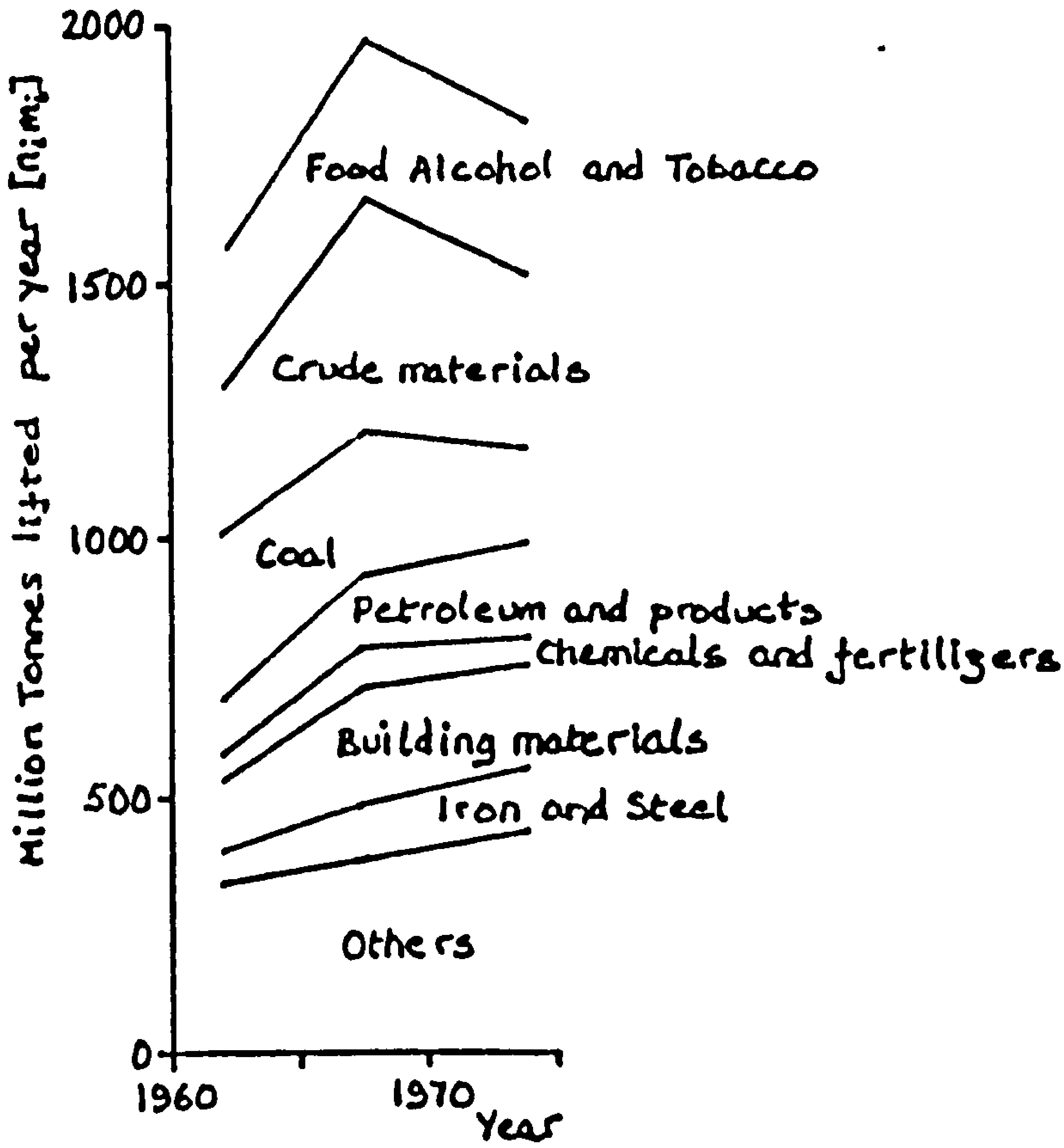

Figure 1.8 Tonnes lifted per year in GB by all modes: by commodity

As in the previous analysis the average distance over which each commodity was moved was found by dividing the tonne-km moved per year by the tonnes lifted per year. The results of doing this are shown in Figure 1.9.

To find the average number of moves made by each commodity it is necessary to know the quantity of commodities produced each year. However the total production of a commodity is not the measure required. For example in the chemical industry the total production of all chemicals is larger than that which is used by all users other than the chemical industry itself. This is because many chemicals are used in the production of other chemicals. What is required is the net production of each commodity. That is the quantity which goes to all users of the commodity other than the industry which produces it. I developed a method for determining net production which I explain in Appendix 3. In the appendix I use 1968 as an example and I describe how I made an estimate of the net production of the eight commodities. The net production of five of these

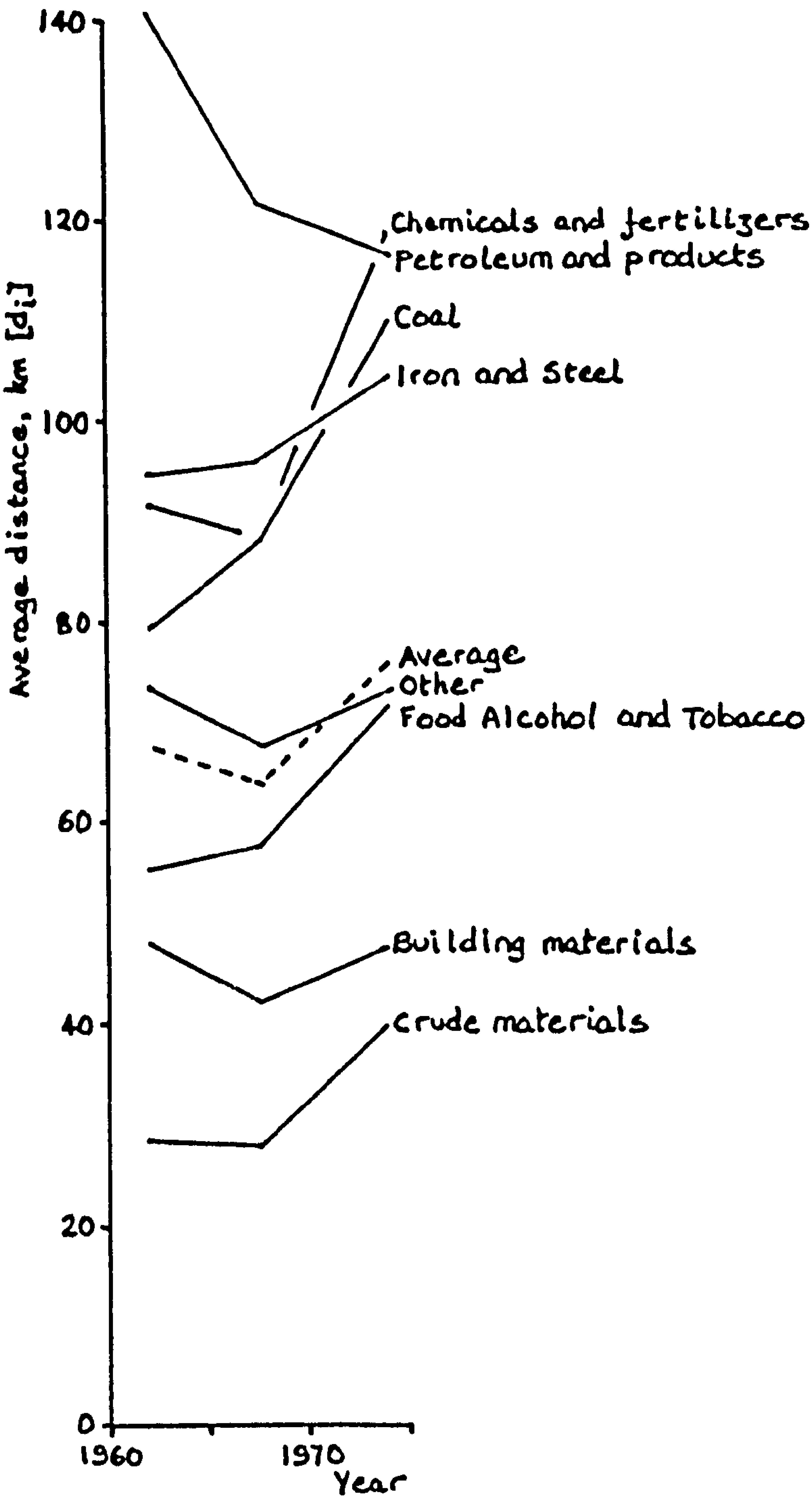

Figure 1.9 Average distances over which commodities are moved in GB by all modes

commodities is very similar to the total production since very little of them are used in their own production.

Consequently it was possible to estimate the net quantities produced in 1962 and 1974. I did this by assuming that the ratios of net to total production were constant in the 3 years. These, along with the tonnes of each commodity lifted per year, and average number of moves, are shown in Tables 1.1, 1.2 and 1.3 for 1962, 1968 and 1974 respectively.

Table 1.1 Average Number of Moves in 1962

Commodity	Supply million tonnes	Goods lifted million tonnes	Average number of moves
Food	90	283	3.1
Minerals	244	279	1.1
Coal	202	322	1.6
Petroleum	64	101	1.6
Iron and Steel	30	78	2.6

Table 1.2 Average Number of Moves in 1968

Commodity	Supply million tonnes	Goods lifted million tonnes	Average number of moves
Food	90.5	314	3.5
Minerals	337.1	465	1.4
Coal	171	285	1.7
Petroleum	97.8	147	1.5
Chemicals	18.7	75	4.0
Building materials	42.4	235	5.5
Iron and Steel	36.9	103	2.8
Other	53.9	389	7.2

Table 1.3 Average Number of Moves in 1974

Commodity	Supply million tonnes	Goods lifted million tonnes	Average number of moves
Food	90	290	3.2
Minerals	371	357	1.0
Coal	111	179	1.6
Petroleum	117	174	1.5
Iron and Steel	37	107	2.9

The average number of moves are also shown in Figure 1.10 [2].

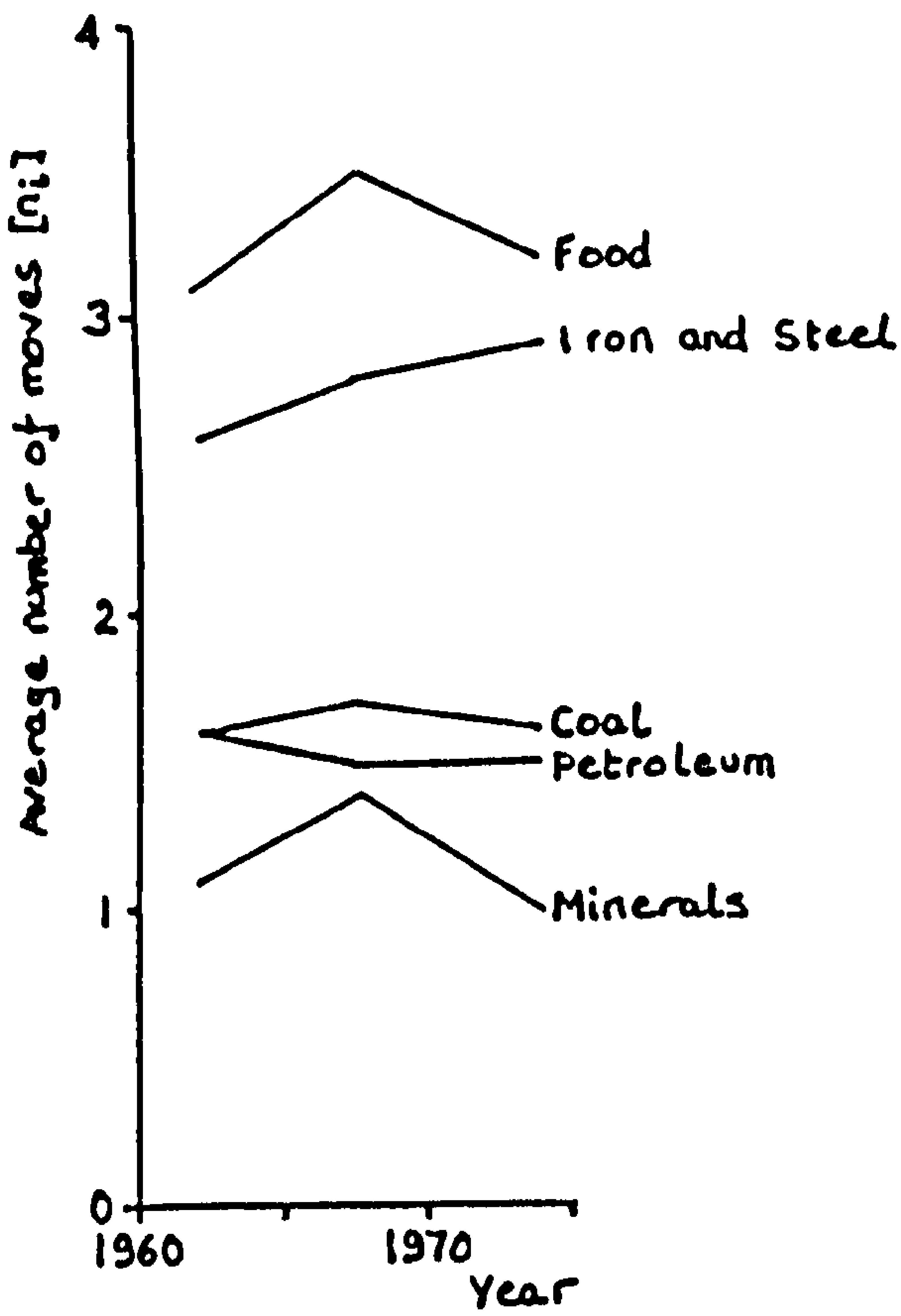

Figure 1.10 Average number of moves

The total supply of petroleum in the UK, tonnes lifted per year and tonne-km moved per year are shown in the Digest of UK Energy Statistics (Department of Energy annual) for the years 1965 to 1975. From these it is possible to find the number of moves and average distance moved for petroleum. These along with the supply of petroleum are shown in Figure 1.11.

The resulting tonne-km per year of petroleum moved are shown in Figure 1.12.

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[2] The same note of caution should be raised about the incompatibility of the tonnes of supply per year (UK basis and the tonnes lifted per year (GB basis, with packaging) as in the preliminary analysis.

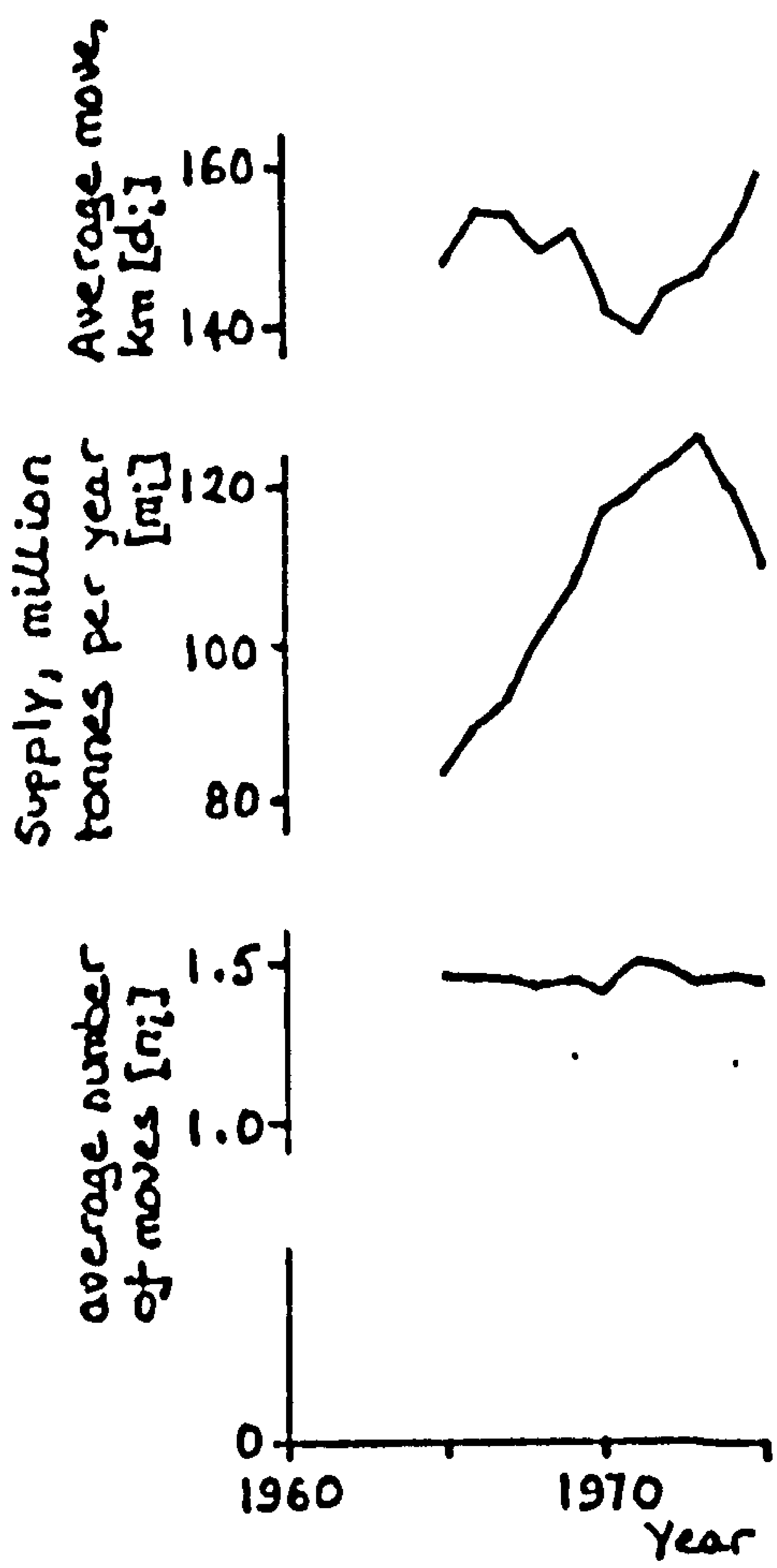

Figure 1.11 Supply, average number and length of moves of Petroleum and products in the UK

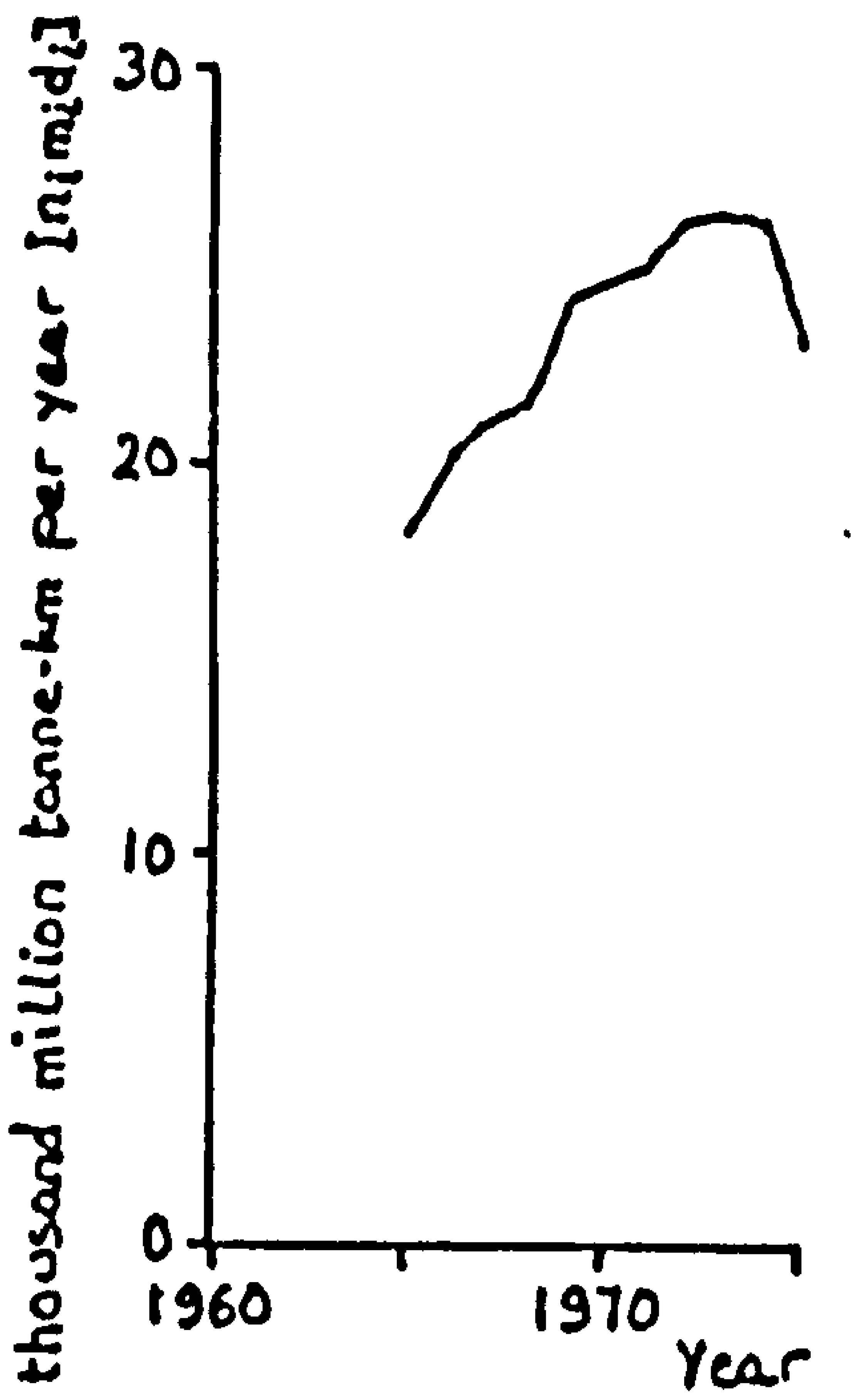

Figure 1.12 Movement of Petroleum in the UK

It should be noted that this is for the United Kingdom rather than for Great Britain, so Figures 1.7, 1.9 and 1.10 are not compatible with Figures 1.11 and 1.12. The average number of moves in Figures 1.10 and 1.11 are very similar. However it is very unlikely that the differences in average length of haul between Figures 1.9 and 1.11 can be accounted for by Northern Ireland. I could find no explanation for this difference.

As in the preliminary analysis the relationships can be expressed mathematically.

Let

n_i = number of times commodity i is moved
m_i = net production of commodity i per year
d_i = average distance over which commodity i is moved
M_i = tonnes of commodity i lifted per year
T_i = tonne-km of commodity i moved per year

where there are p commodities.

Then

$$M_i = m_i n_i \qquad i = 1,p$$
$$\therefore \; n_i = M_i / m_i \qquad i = 1,p$$
$$T_i = M_i d_i \qquad i = 1,p$$
$$\therefore \; d_i = T_i / M_i \qquad i = 1,p$$

Also, using the same symbols as in the preliminary analysis:

$$M = \sum_{i=1}^{p} M_i = \sum_{i=1}^{p} m_i n_i$$

$$T = \sum_{i=1}^{p} T_i = \sum_{i=1}^{p} m_i n_i d_i$$

$$n = \sum_{i=1}^{p} m_i n_i / m$$

and $$D = \sum_{i=1}^{p} m_i n_i d_i \Big/ \sum_{i=1}^{p} m_i n_i$$

However, because m is primary inputs and imports, whereas m_i is the output of commodity i, some of which goes into the commodities, note that:

$$m < \sum_{i=1}^{p} m_i$$

1.5 Further work

The next stage in this work would be the compilation of tonnages lifted per year and tonne-km moved per year of different commodities on each mode of transport for as many years as possible (Approximately 1950-78). With suitable adjustments to the commodity classifications these figures could then be combined to get totals for each commodity by all modes of transport. I have listed the sources of data which I have identified, and the problems with these sources, in Appendix 1.

As well as finding the quantities lifted and moved per year for each commodity the net physical volume of each commodity produced could be found. Further details of how this could be done and some of the likely problems are given in Appendix 3. Having obtained the time series of net supply, average number of moves, and average distance moved for each commodity, it would be possible to look for explanations for the values and time trends found.

Having put this data together, it would also be possible to do a disagregation by mode. If subscript j represents mode, using the same symbols as before, the total tonne-km moved per year is

$$T = \sum_{i=1}^{p} m_i \sum_{j=1}^{q} n_{ij} d_{ij}$$

where

n_{ij} = number of times commodity i is moved by mode j
d_{ij} = average distance over which commodity i is moved by mode j
and there are q modes.

1.6 Conclusions

From this work I learnt several things:

(a) There is insufficient data to even approach an "ideal" model (multi-region input-output). However if such a model could be constructed it would be very difficult to use as a basis for forecasting because of the problems of making large numbers of projections to drive the model (i.e. of final demand for each region in the model).

(b) There are problems with data which does exist. For example published statistics are often incomplete without adequate warning. An example of this is the above mentioned problem of the incomplete list of imports given in the Annual Abstract of Statistics. Also the commodity classifications between the different modes are inconsistent.

(c) Greater disagregation of available data does not lead to any understanding of the causes for the underlying trends. For example a constant number of moves for a commodity does not explain why that ratio has remained constant and so is a poor basis for making a forecast.

2. VEHICLE REFUELLING INFRASTRUCTURE

2.1 Introduction

Another avenue of my enquiries started with the Future Transport Fuels (FTF) study (Chapman, Charlesworth and Baker 1976). The FTF study was a short appraisal of the likely alternatives to petrol and diesel as transport fuels in 2025, a notional date by which natural petroleum was assumed to have run out or be in short supply. We looked at many routes between primary sources of energy and transport output. Of these routes the two which seemed most promising in the UK were either liquid fuels derived from coal or electricity stored in batteries [1]. On a primary energy to transport output basis we concluded that the electric vehicle option would be more efficient.

As well as looking at the energy conversion processes directly involved we also examined the choice of transport fuel within the wider energy economy. By examining several energy supply and demand scenarios we concluded that the battery car would be preferable because:

(a) In primary energy terms it would be slightly more efficient.

(b) The liquid fueled vehicle scenarios required all the UK's coal for liquid fuel production, whereas in the electric vehicle scenarios there would be sufficient coal available to make gas for heating. Gas is more efficient for heating than the electricity which would be used in the liquid fuel scenario.

(c) The seasonal variations in transport demand as compared with space heat demand are such that the electricity system would work at a higher load factor in the electric vehicle scenario.

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[1] I have yet to understand how liquid fuels can be derived from electricity stored in batteries.

The FTF study led to a further study which looked at vehicle refuelling infrastructures (the VRI study). It started from the FTF study and filled in some parts in more detail. The VRI study involved looking at liquid fuel and battery vehicle scenarios (based on those in the FTF study) in some detail to check that there would be no unforeseen problems over their required refuelling infrastructures. It also contained a more detailed analysis of the electricity system operation. The initial aims of the VRI study were to describe and compare in energy and cash terms the refuelling infrastructures required in 2025 by a complete fleet of battery electric road vehicles and of a complete fleet of vehicles running on liquid fuel derived from coal. (The study of the electric vehicle case was to include an examination of improvements required to the grid, however this could not be covered because of the lack of geographical data on road transport.)

Review of other work

In the Electrical Research Association Study reported by Weeks (1978), electric vehicles were to be refuelled only by battery exchange. The reasons given by Weeks for the ERA study being restricted to battery exchange, as the only method of refuelling, were "because home charging would upset the economics of the infrastructure, which would be underutilised, and battery life would be prejudiced by a reduction in quality control of the charging process" (Weeks 1978, p11). However we believed these reasons were wrong because the primary determinant of the economics of exchange stations is their individual turnover rather than how many there are of them, and with suitably designed chargers there should be no problem with the quality of the charging process.

Reasons for conducting the VRI study

The reasons for conducting the VRI study were a desire to check out the implications, in terms of changes to the electricity system as opposed to changes to the liquid fuel manufacturing processes of having one or other type of vehicle fleet. It was recognised that neither a wholly electric nor a wholly liquid fueled fleet is likely but it was felt that an either/or analysis would highlight the differences between them and that any chosen level of mixture of the two traction types would be arbitrary.

The definition of refuelling infrastructure as used in the VRI study is perhaps best made by reference to Figure 2.1.

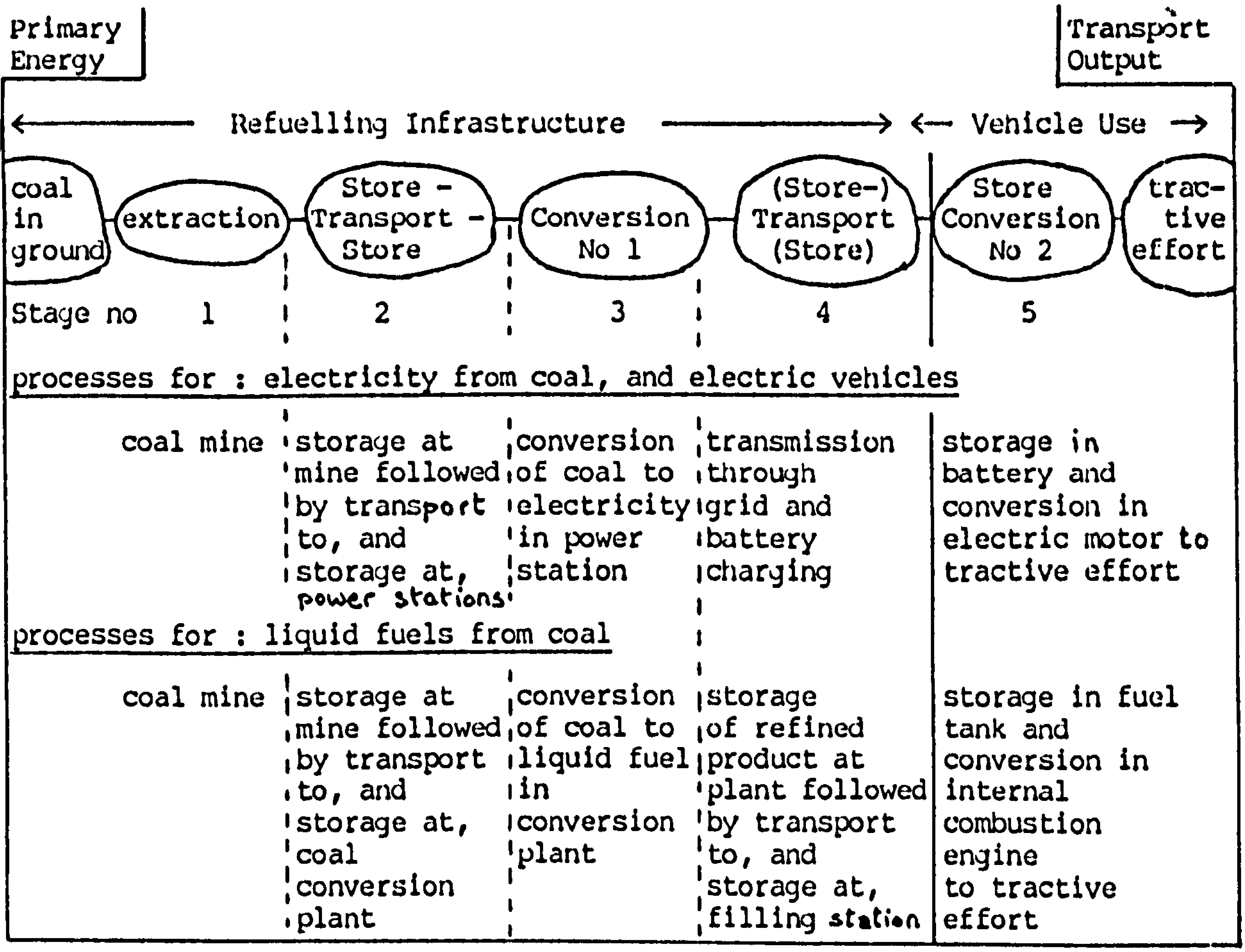


Figure 2.1 Components of the refuelling infrastructures

This figure illustrates the pathway from primary energy to transport output. This consists of five stages. These are extraction, movement to a conversion plant (power station or 'coalplex'), conversion to a fuel (electricity or liquid), movement to the vehicle, and conversion in the vehicle to tractive effort. Also involved at several points are storage. It is the first four of the stages (up to the point at which the fuel is placed in the vehicle) which were considered to be refuelling infrastructure.

In the FTF study we identified significant advantages in other parts of the economy due to electric road vehicles. The allocation of coal as a liquid fuel to road transport could have considerable effect on other sectors which may require other coal derived products such as gas. When coal is in short supply such action (using coal for liquid fuels) may force these other sectors to use a 'second' choice fuel (such as electricity) for some applications (such as space heating) which leads to a less efficient use of primary energy and higher consumer costs. Consequently when making cost comparisons between the two refuelling infrastructures, comparisons were also made between the total cost of energy within the economy.

2.2 Structure of the VRI study

The VRI study made comparisons between two transport fuel scenarios for the year 2025. One involved an all electric road vehicle fleet and the other an all liquid fueled vehicle fleet. Both scenarios started with vehicle design and performance projections. Official road transport forecasts were used in both scenarios to obtain projected transport energy demands for 2025. Other starting points in the VRI study were projections of energy supply and of energy demands in the remainder of the economy of 2025 plus projected conversion efficiencies of useful to delivered and of delivered to primary energy. These projections were used in both of the scenarios.

From these starting points the VRI study followed two major strands. The first was the analysis of the two refuelling systems. For electric vehicles it was assumed that the main method of refuelling would be by insitu recharging of batteries and that battery exchange would be used to overcome the range limitations of electric vehicles. To determine the number and size of battery exchange stations required it was necessary to make a detailed analysis of the journey patterns of the different types of road vehicles. The number and size of liquid fuel stations were projected from current trends in size and numbers.

The second strand of the VRI study was an analysis of all energy demands in the UK and of the electricity supply system. First projections of road transport energy demand were made for both electric and liquid fuelled vehicles, and combined with the projected demands in the remainder of the economy. The useful energy demands in the remainder of the economy were broken down into fixed demands, which had to be met from one source, and free demands which could be met from several sources. Fuels were then allocated to road transport followed by each of the fixed demands and then to each of the free demands, up to supply constraints imposed by the projected primary supply availabilities. The demands for electricity were then used in an hourly electricity demand model to determine the required size of generating plant, the breakdown of this plant between coal and nuclear and the amount of coal required for the coal fired plant. It was then necessary to return to the fuel allocation stage to check that the limit on coal production had not been breached.

Finally the two strands were combined to get estimates of fuel costs per vehicle and the total costs of fuels for all energy uses. These cost estimates were made on the basis of notional cost breakdowns (into plant capital and running costs, transmission costs and overheads) for electricity, liquid fuels and gas.

Major assumptions

In developing the two scenarios many assumptions were made. The major assumptions made were:

(a) Road transport will follow DoE/DTp forecasts

(b) By 2025 there will be no (or negligible) indigenous supply of oil or natural gas.

(c) In 2025 the UK will be able to produce 200 to 250 million tonnes of coal per year.

(d) The UK will remain energy self sufficient after the depletion of North sea oil and gas.

(e) Gross domestic product will grow at the following rates 1975-2000 at 2% and 2000-2025 at 1.5%.

(f) There will be a strong preference to use gas for space heating and that the only other fuel available for space heating will be electricity.

Some of the other assumptions made and developments made upon the original FTF study were:

(g) In both scenarios road vehicles would fulfill the same demands and follow the same journey patterns.

(h) High energy density batteries will be available with energy densities of 500 MJ/tonne (140 kWh/tonne).

(i) Electric batteries will all be hired and not owned.

(j) There will be standardisation of vehicles and batteries (in particular size, shape and terminal layout) to allow for battery exchange.

(k) Liquid fuels derived from coal will be of the petrol/diesel type which will be stored, dispensed and used in the same way as today.

2.3 Details of the VRI study

Vehicle Design

Unlike the FTF study, the VRI study made and used projections of delivered energy per vehicle kilometre for road transport instead of useful energy per vehicle kilometre. The original intention had been to model vehicle-traffic interactions for both electric vehicles and internal combustion engined vehicles. However the modelling of the latter proved difficult and was dropped in favour of making projections of vehicle energy consumptions on the basis of assumed savings over today's levels.

In the VRI study four main categories of vehicle were distinguished (Car, Van, Goods and Bus). For the analysis of the electric vehicles Goods vehicles were further split into Small, Middle and Large corresponding to internal combustion engined goods vehicles of the following Unladen Weights: 1.5-3 tons, 3-5 tons and 5+ tons. The efficiencies of the various parts of the drive system were taken as shown in Table 2.1.

Table 2.1 Electric Vehicle Efficiencies

	efficiency
Battery discharge	0.9
Controller	0.95
Motor	0.92
Transmission	0.95
Overall	0.75

sources: Corbett & Roerig (1980)
Lee & Corbett (1979)
Charlesworth (1979)

These were combined with the design parameters shown in Table 2.2 and used in a road Vehicle Driving Cycle Model which was principally developed by Charlesworth (1979, pp 176 - 201).

Table 2.2 Electric Vehicle Design Parameters

Vehicle		Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
traction efficiency %				0.75			
battery mass	kg	300	500	900	1400	3000	1400
GVW	kg	1350	2400	6500	11500	35000	13500
payload	kg	400	900	3000	5000	21000	4060
drag coeff.	.	0.4	0.5	0.85	0.95	1.0	0.85
frontal area	sq.m	1.5	1.5	3.9	7.0	9.0	7.5
Rolling resistance	kgf/kg	0.015	0.013	0.01	0.0075	0.0075	0.0075
battery energy density[1]	MJ/kg	0.5	0.5	0.5	0.5	0.5	0.5
battery power density[1]	kW/kg	0.12	0.12	0.12	0.12	0.12	0.12

sources: Charlesworth (1979), Gyenes (1978)

notes: 1 advanced battery such as Sodium-Sulphur or Nickel-Chloride

The model can 'drive' the vehicle over a predefined driving cycle. Those used were the ECE15 Urban, constant speed 56 mph, and constant speed 75 mph cycles (United Nations, Economic Commission for Europe, Inland Transport Committee 1970). The resultant estimates of power requirements, fuel consumption and range for vehicles at full and half load are shown in

Table 2.3.

Table 2.3 Estimates of Power, Fuel Consumption and Range

ECE Driving Cycles, Full load

Vehicle	Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Maximum Power kW						
required	17	22	84	162	275	158
available	36	60	108	168	360	168
Fuel Consumption MJ/km (in vehicle energy)						
Urban	0.42	0.66	1.70	2.76	7.43	3.12
Constant 56mph	0.43	0.58	2.07	3.86	6.17	3.82
Constant 75mph	0.67	0.87	3.37	6.47	9.72	6.33
Range km						
Urban	360	378	265	253	202	224
Constant 56mph	349	434	218	181	243	183
Constant 75mph	225	287	133	108	154	111

ECE Driving Cylces, Half load

Maximum Power kW						
required	16	21	82	159	230	156
available	36	60	108	168	360	168
Fuel Consumption MJ/km (in vehicle energy)						
Urban	0.36	0.55	1.37	2.29	5.44	2.73
Constant 56 mph	0.41	0.54	1.97	3.73	5.66	3.72
Constant 75 mph	0.65	0.83	3.27	6.35	9.20	6.22
Range km						
Urban	414	454	328	306	276	256
Constant 56 mph	366	465	229	187	265	188
Constant 75 mph	232	300	137	110	163	112

The three sets of fuel consumption and range estimates were averaged as shown in Table 2.4 which also includes allowances for accessories and heating.

This averaging was for vehicles with half load and took account of the proportion of travel under the three conditions.

The maximum demand for accessories is likely to be 550W (being 250W for Headlights, sidelights, flashers, panel lights etc., and 300W for wiper motor, heater blower etc.). In view of the short time that these accessories are in use it was assumed that they would add an additional

Table 2.4 Electric Vehicle Energy Consumption and Range

Vehicle[1]		Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Proportion of traffic[2]							
Urban		0.496	0.494		0.323		0.568
Rural (Constant 56 mph)		0.418	0.441		0.677		0.363
Motorway (Constant 75 mph)		0.086	0.065		-3		0.069
Fuel Consumption	MJ/km	0.41	0.56	1.78	3.26	5.59	3.33
Accessorys	MJ/km	0.04	0.04	0.04	0.04	0.04	0.06
Total[4]	MJ/km	0.45	0.60	1.82	3.30	5.63	3.39
Heating[5]	MJ/km	0.09	0.08	0.05	0.05	0.10	0.15
Energy Stored	MJ	150	250	450	700	1500	700
Average Range	km	340	410	250	210	266	210

notes: 1 all vehicles at half load
2 from Department of Transport (annual a)
3 goods vehicles taken at 56 mph on motorways
4 in vehicle energy
5 average in vehicle energy, supplied by a liquid fuel

energy demand of 0.03-0.06 MJ/km. Because the internal combustion engine acts as a free heat source there has to date been no incentive to reduce heat losses in road vehicles. Instead large heaters are used (typically 6-9kW which compares with the average domestic central heating system which is also rated at 6-9kW). The electric vehicle has no such 'free' heat source and will certainly be better insulated and use heat recovery on ventilated air. Estimates of average heating requirements are given in Table 2.4. These compare with the requirements for currently available heaters (Yonwin 1979), and were assumed to be provided for by a liquid or gas derived from coal.

In the VRI study liquid fuelled vehicles were broken down into groups. (Cars by engine size, Vans and Goods vehicles by unladen weight and Busses by seating capacity). Present fuel consumptions, assumed improvements in efficiency and the resultant future fuel consumptions are shown in Table 2.5.

The improvements in efficiency are likely to be due to the use of lighter materials to reduce body mass, better styling to reduce air drag and better tyres and braking systems to reduce rolling resistance. Also shown

Table 2.5 Present and Projected Liquid Fuelled Vehicle Consumptions

Vehicle	group	Normalised population 1976	2025[1]	Fuel Consumption Present MJ/km	Improvement %[2]	Future MJ/km
Car	< 1	0.16	0.15	2.6	40	1.6
by	1-1.5	0.46	0.50	3.4	40	2.0
engine	1.5-2	0.30	0.32	4.1	40	2.5
size	2-3	0.05	0.02	5.3	40	3.2
litre	3+	0.03	0.01	6.3	40	3.8
	Total/av	1.00	1.00	3.66	41.5	2.14
Van	<0.8	0.38	0.25	3.0	40	1.8
by	0.8-1	0.16	0.24	3.2	40	1.9
ULW	1-1.5	0.46	0.51	4.4	40	2.6
ton						
	Total/av	1.00	1.00	3.68	38.6	2.26
Goods	1.5-2	0.11	0.10	5.1	20	4.1
by	2-3	0.23	0.23	7.3	20	5.8
ULW	3-5	0.26	0.10	8.7	20	6.7
ton	5-8	0.22	0.32	12.5	20	10.0
	8+	0.18	0.20	16.0	20	12.8
	Total/av	1.00	1.00	3	3	3
Bus	8-32	0.12	0.12	7.3	20	5.8
by	32-48	0.30	0.28	10.6	20	8.5
seats	48+	0.58	0.60	13.2	20	10.6
	Total/av	1.00	1.00	11.71	19.6	9.41

notes: 1 projected
2 after Waters and Laker (1980) and Waters (1980)
3 range varies with size (see Table 2.7)

in Table 2.5 are normalized population breakdowns for 1974 and projected for 2025. It was assumed that, except for goods vehicles, within each group of vehicles the average range is the same. (For example see the weekly mileages of cars by engine capacity in Gray (1969)). Consequently the normalised populations also represent normalised total annual ranges and can be used as weighting factors to find average fuel consumptions.

Transport Projections

Projections of vehicle numbers and total kilometers were made by extending the DoE/DTp lower forecasts (Department of Transport annual a) from 2010 to 2025. The lower forecasts were used because these allow the best correspondence between GDP assumptions used in the VRI study and the forecasts (for example see Tanner (1974, p6)). The results of doing this are shown in Table 2.6.

Table 2.6 Vehicle and Vehicle Kilometer Projections for 2025

Vehicle	Number of vehicles million	Total vehicle kilometers '000 million
Car	26.4	418
Van	2.0	51
Goods	1.1	49
Bus	0.09	3.4

source: after Departmentof the Environment (1975c)

Energy Demand Projections

Average goods vehicle fuel consumptions for both electric and liquid fuelled vehicles were found by using 1974 average annual ranges (Department of Transport 1979a) in conjunction with the projected 2025 population breakdown to derive normalized average annual ranges for 2025. These together with projected numbers and vehicle kilometers for goods vehicles are shown in Table 2.7.

Table 2.7 Goods Vehicles, Vehicle km and Fuel Consumptions

Size		Small		Medium	Large		Total/av
ULW	ton	1.5-2	2-3	3-5	5-8	8+	1.5+
Vehicle km/yr (1974)	'000	19	19	27	30	50	-
normalized population (2025)		0.10	0.23	0.10	0.32	0.25	1.00
number of vehicles	million	0.11	0.25	0.11	0.35	0.28	1.1
normalized vehicle km (2025)		0.06	0.14	0.09	0.31	0.40	1.00
total vehicle km '000	million	3.0	6.8	4.2	15.0	20.0	49
vehicle km/yr (2025)	'000	27.2	27.2	38.7	43.0	71.7	-
Liquid Fuel Consumption	MJ/km	4.1	5.8	6.7	10.0	12.8	9.88
Electrical Energy	MJ/km	1.82		3.30	5.63		4.66
Heating	MJ/km	0.05		0.05	0.10		0.09

Total projected fuel consumptions for both electric and liquid fueled vehicles are shown in Table 2.8.

Table 2.8 Projected Vehicle Fuel Consumptions

Vehicle	Total Vehicle km/yr '000 million	Liquid Fuelled consumption		Electric Vehicles electric energy		heating	
		MJ/km	PJ/yr	MJ/km	PJ/yr	MJ/km	PJ/yr
Car	418	2.14	895	0.45	188	0.09	38
Van	51	2.26	115	0.60	31	0.08	4
Goods	49	9.88	484	4.66	228	0.09	4
Bus	3.4	9.41	32	3.39	12	0.15	1
Total			1526		459		47

These were found by combining the previously found fuel consumptions with total vehicle kilometers.

Analysis of Journeys

Because of the limited ranges of the electric vehicles they would be unable to do all today's journeys on one battery charge. Consequently it was assumed that, to enable electric vehicles to perform journeys of any length, battery exchange stations would be provided. To find the number of exchanges required on any day, it is necessary to know the distribution of distances covered on that day, and average distance travelled before an exchange is required. For this purpose a 'long journey' range was postulated which is somewhat shorter than the average range due to assumed higher average speeds on long journeys. The long journey range was taken to be the average of the 56mph and 75mph ranges for cars, vans and buses and the 56mph range for goods vehicles. The average 'exchange range' was then taken to be this 'long journey' range less 20km (0.5 of an assumed 20km exchange station spacing, plus a 10km safety margin.) (Later in the study it was found that 2500 stations would be required. These could be spaced on average at 19km on all trunk and principal roads (Department of Transport annual a)). These ranges plus the average discharge factor (a measure of how far the average battery is discharged on exchange) are shown in Table 2.9.

To obtain an estimate of the total number of battery exchanges per year the number required on an average day was estimated. To estimate the size

Table 2.9 Exchange Ranges for Electric Vehicles

kilometers

vehicle[1]	Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Urban	414	454	328	306	276	256
Constant 56mph	366	465	229	187	265	188
Constant 75mph	232	300	137	110	163	112
"Long journey"[2]	300	380	230	190	260	150
"exchange"	280	360	210	170	240	130
av discharge factor	0.93	0.95	0.91	0.89	0.92	0.87

notes: 1 all vehicles at half load
2 car, van and bus at average of 56mph & 75mph, goods at 56mph

of stations required, the number of exchanges required on a peak day were estimated. The peak is likely to occur either on a day of maximum car use or a day of maximum goods vehicle use. Historically these have been a Saturday in August and an October weekday respectively.

The distribution of daily ranges were estimated by taking historic distributions of ranges and adjusting them so that they coincide with the projected number of vehicles in use and the average daily kilometers for each type of vehicle for each of the three days. The proportion of vehicles in use and average daily mileages are shown in Table 2.10.

The distribution of daily ranges for cars was derived from data in Gray (1969) and the 1972-73 National Travel Survey (Department of the Environment 1975a). The distribution of annual and weekly mileages when reduced to a common basis were found to be very similar and it was assumed that the distribution of daily mileages has the same shape. Less data is available for vans and goods vehicles. It was assumed that they will have distributions similar to the distributions of journey lengths. These were obtained from the Sample of Small Goods Vehicles: 1974 (Department of the Environment 1975b) and the Survey of Road Goods Transport 1962 (Ministry of Transport 1964-66). The distribution of daily ranges of buses was obtained from Hellewell (1978).

Table 2.10 Summary of Vehicle Use and Average Daily Milages

vehicle			Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
number	million	(1)	26.4	2.0	0.36	0.11	0.63	0.09
Total annual km	'000 million	(2)	418	51	9.8	4.2	35.0	3.4
Average daily km		(3)	43.4	70	75	105	152	100
Ratio of day's	Aug.Sat	(4)	1.42	0.82		0.34		1.34
to av km	Oct.weekday	(5)	0.98	1.17		1.34		1.13
Proportion of	Aug.Sat	(6)	0.8	0.53		0.21		0.8
vehicles	Oct.weekday	(7)	0.75	0.75		0.8		0.8
in use	Av.day	(8)	0.74	0.63		0.59		0.75
Av daily km of	Aug.Sat	(9)	77	110	127	178	258	170
vehicles	Oct.weekday	(10)	57	110	127	178	258	140
in use	Av.day	(11)	59	110	127	178	258	130

notes: row (1) from Table 2.6 }
row (2) from Table 2.6 } Goods from Table 2.7
row (3) = row (2) / row (1) / 365000
rows (4) & (5) derived from "Monthly and average daily traffic on classified roads: by type of vehicle: 1974" (Department of Transport annual a)
rows (6) to (8) derived from Gray (1969), Department of the Environment (1975b), and Edwards and Bayliss (1970) The figures for Van and Goods are such that the average daily km for the 3 days in rows (9) to (11) are the same
row (9) = row (3) * row (4) / row (6)
row (10) = row (3) * row (5) / row (7)
row (11) = row (3) / row (8)

The derived distributions of daily mileages are shown in Figures 2.2 to 2.7.

On these figures are shown the exchange ranges of each type of vehicle. The proportion of vehicles requiring 1st, 2nd, etc. exchanges, on each of the three days considered, are shown in Table 2.11.

The final column in this table gives an estimate of the number of exchanges required as a proportion of each type of vehicle. It should be noted that these estimates are liable to error as they are based upon the size of the tails of very imperfectly known distributions.

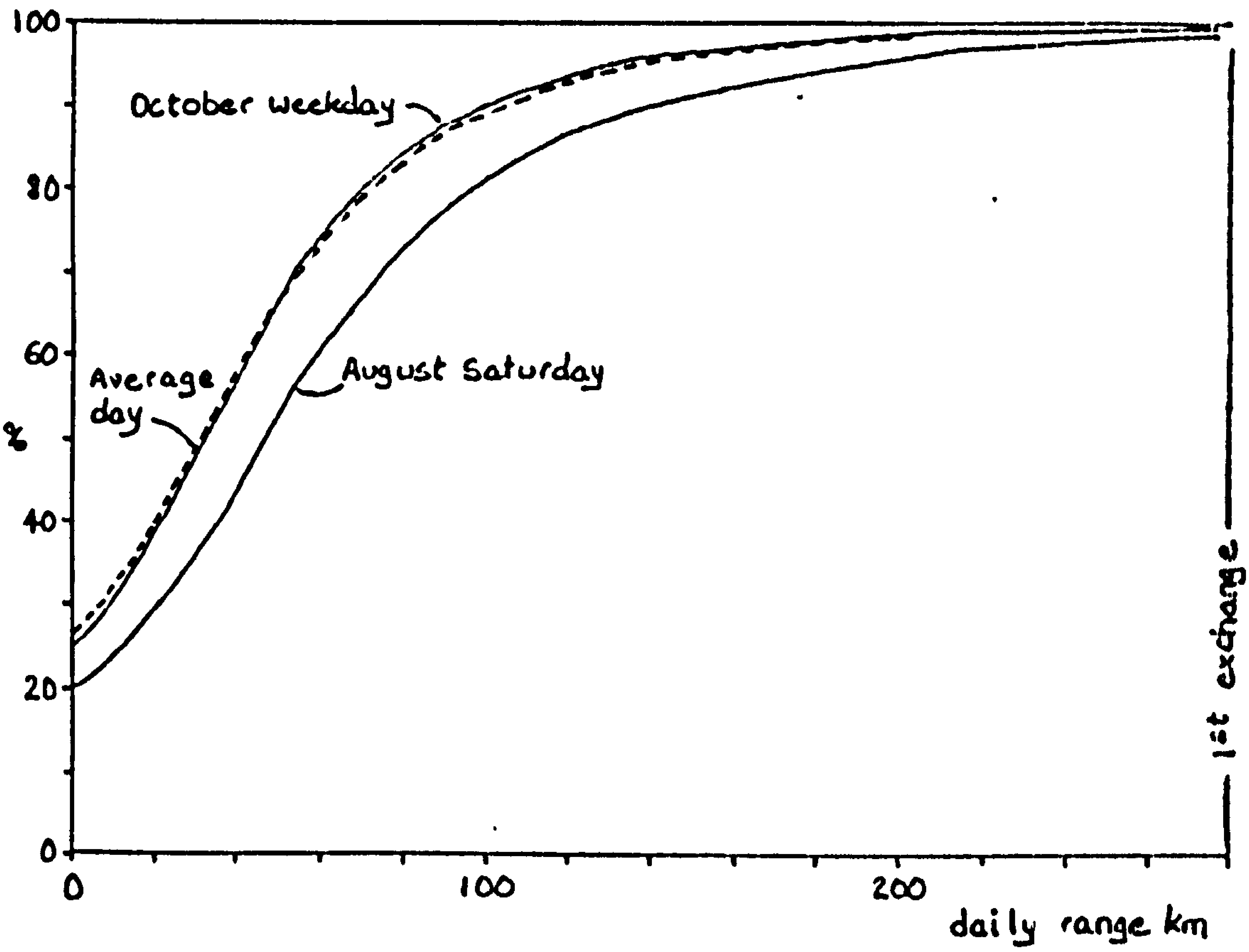


Figure 2.2 Cumulative distributions of daily ranges for cars

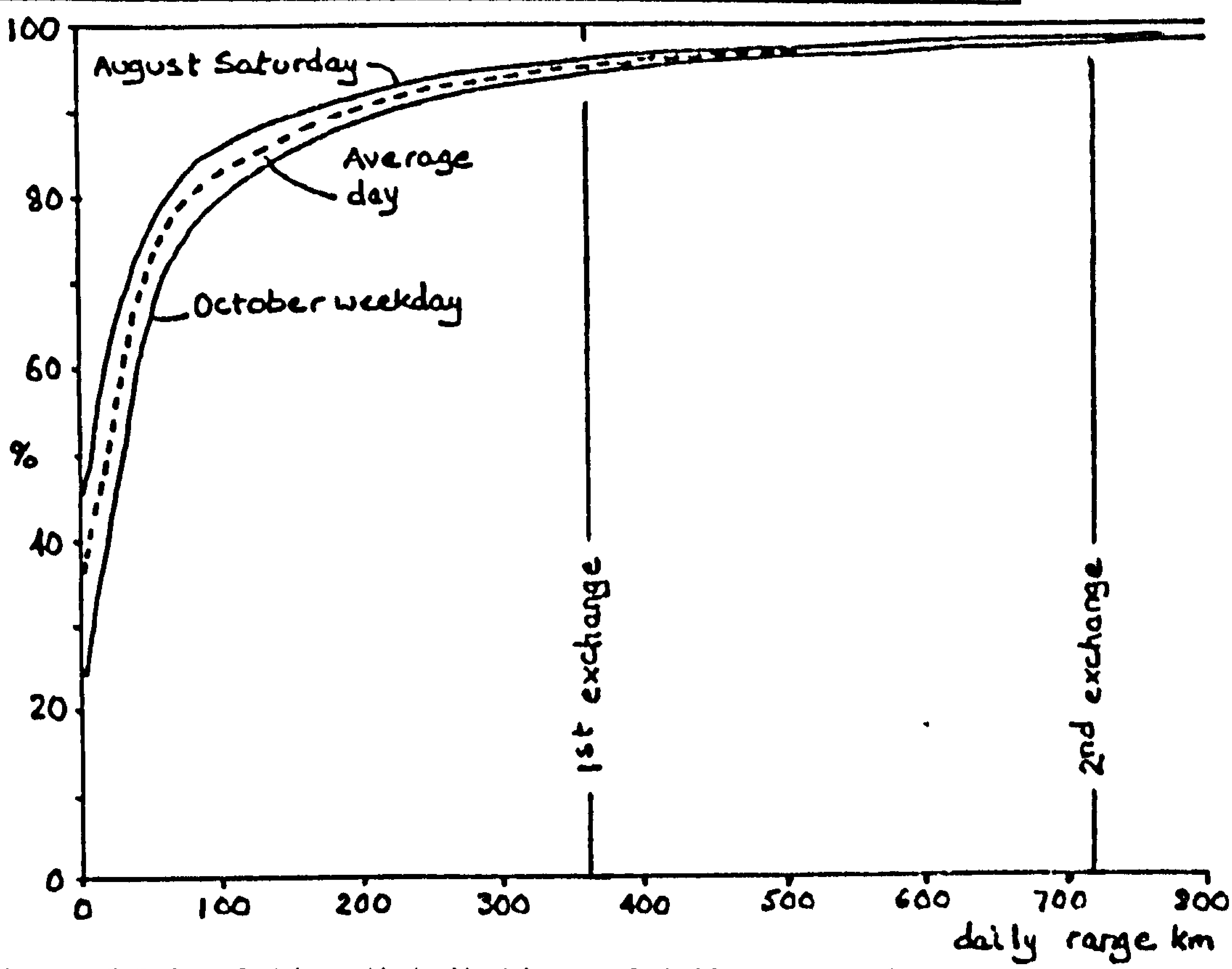


Figure 2.3 Cumulative distributions of daily ranges for vans

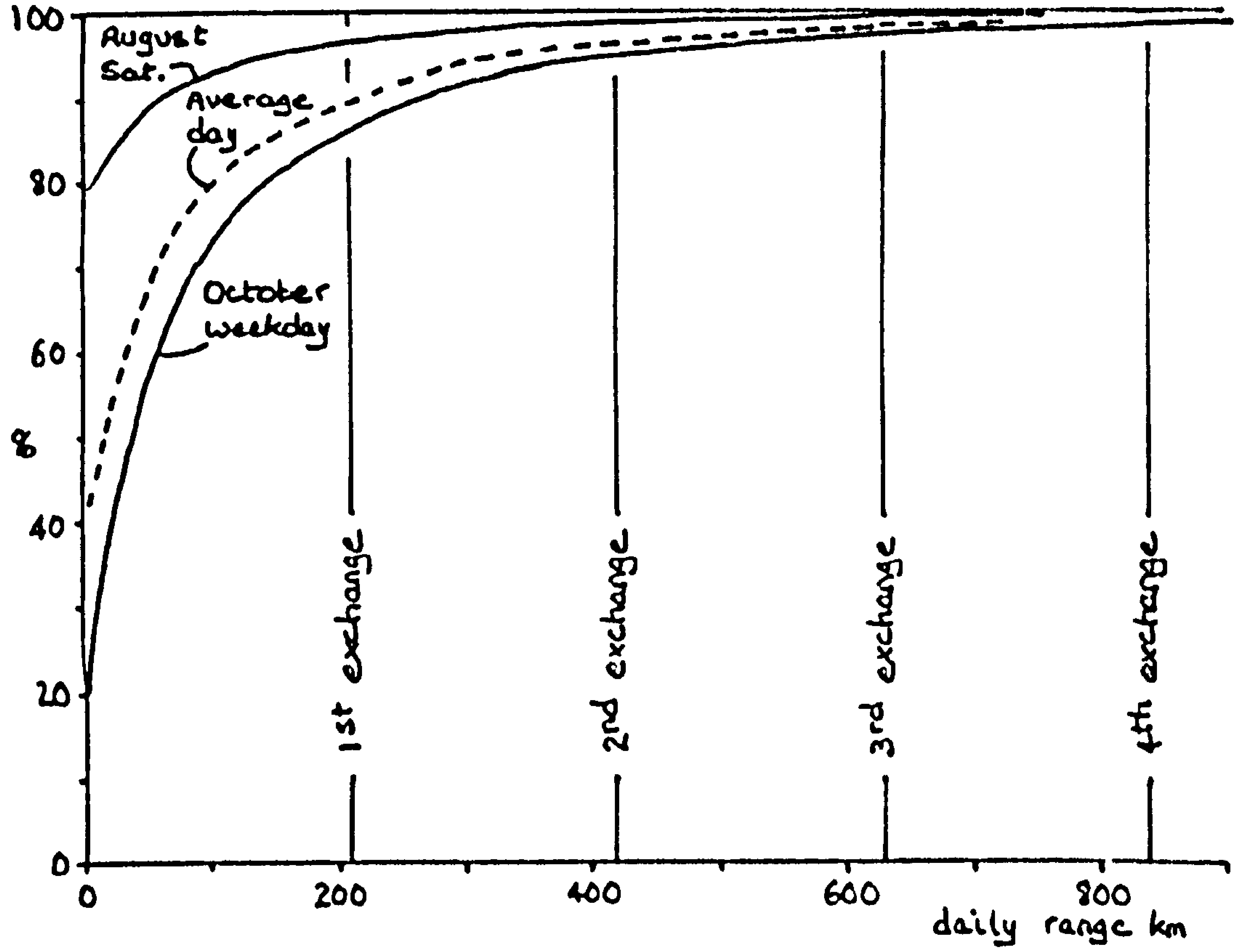


Figure 2.4 Cumulative distributions of daily ranges for small goods

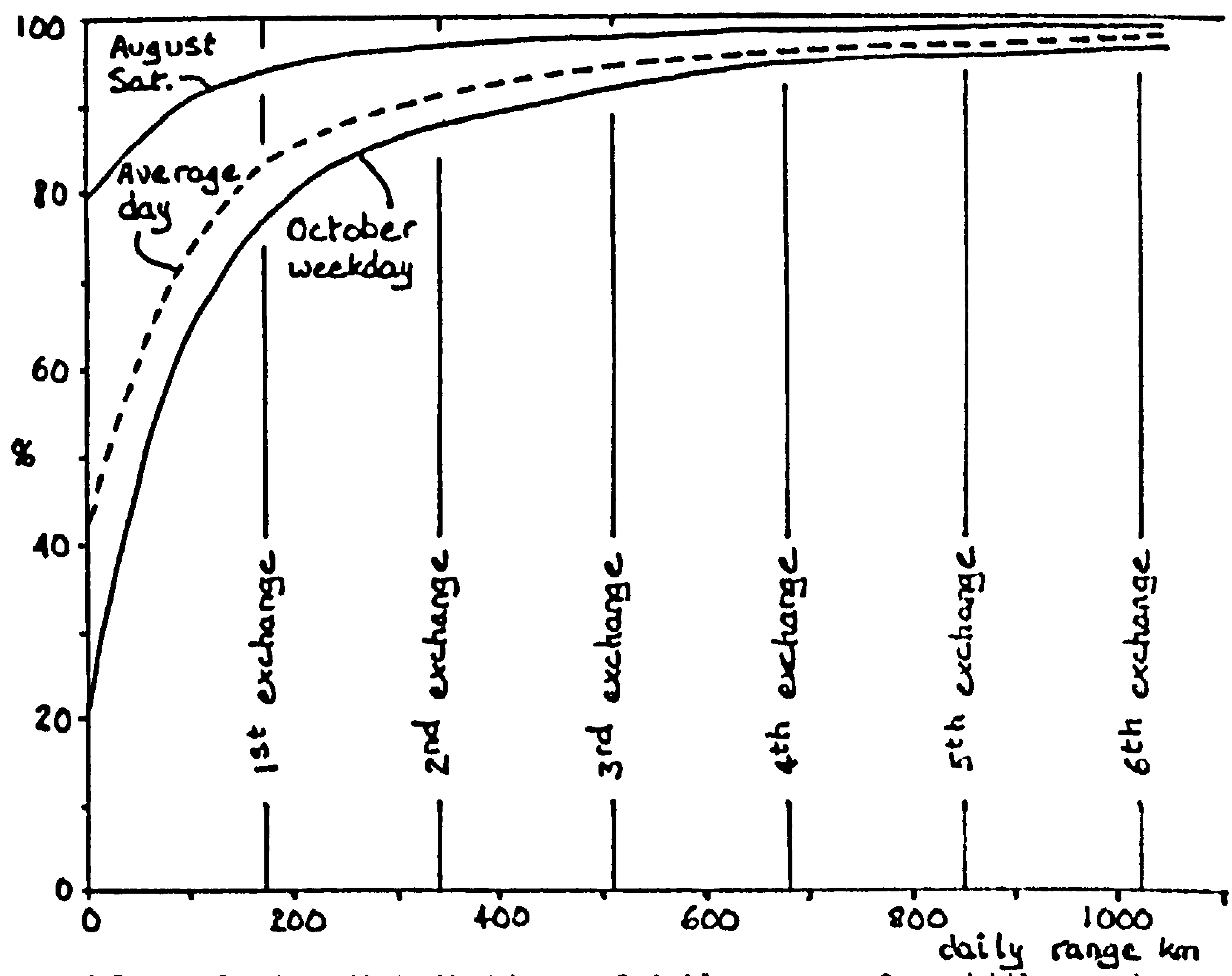


Figure 2.5 Cumulative distributions of daily ranges for middle goods

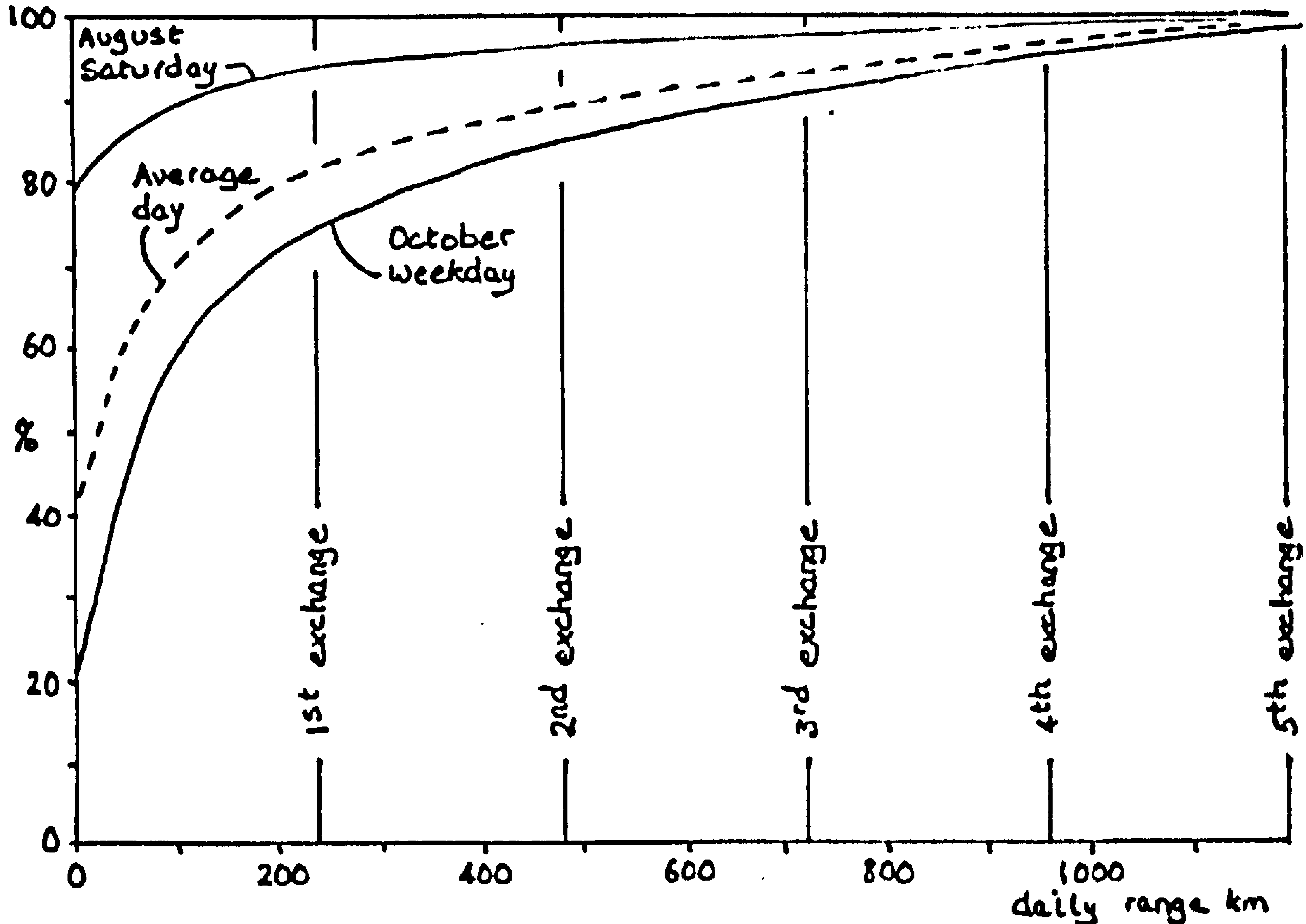


Figure 2.6 Cumulative distributions of daily ranges for large goods

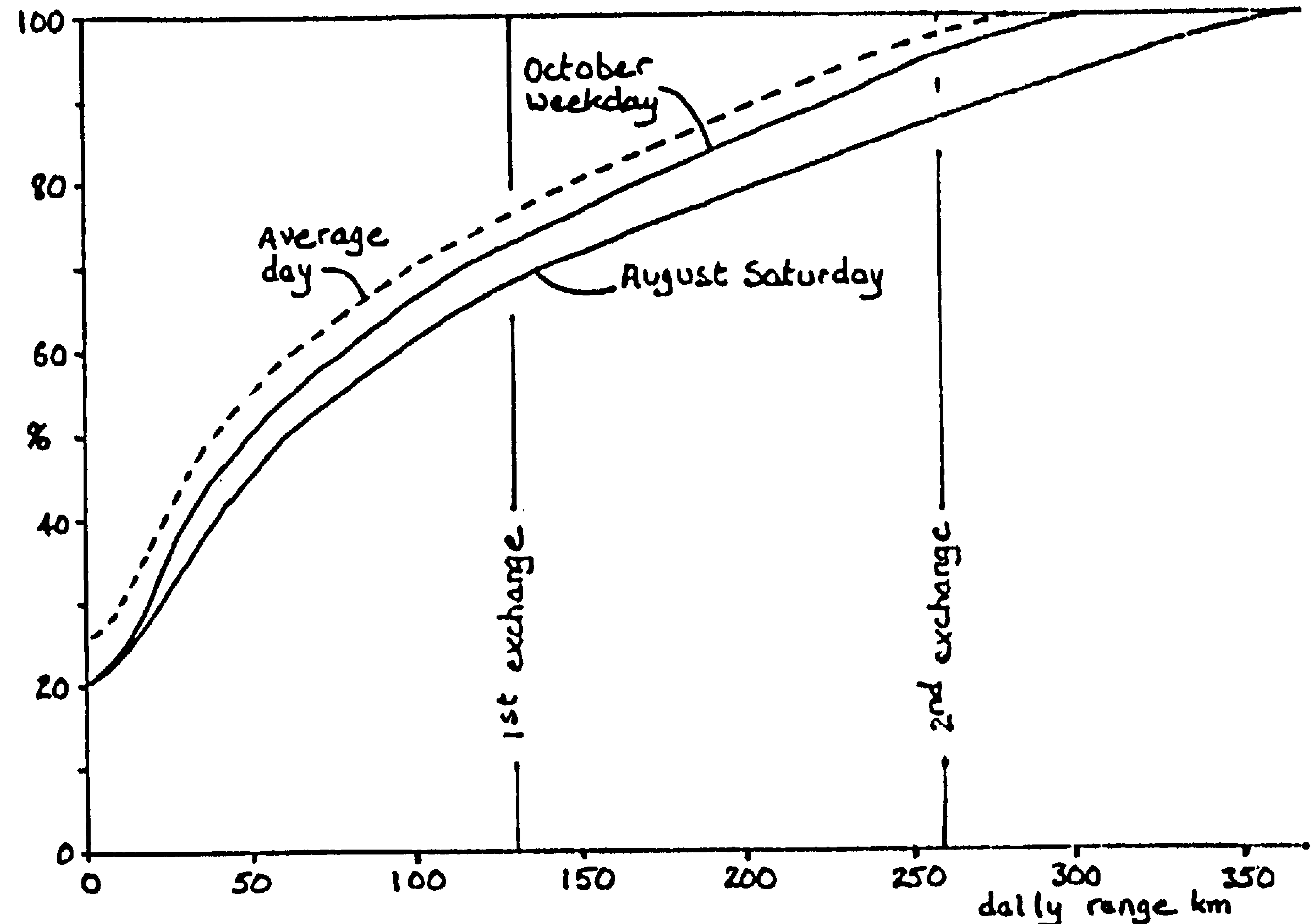


Figure 2.7 Cumulative distributions of daily ranges for buses

Table 2.11 Proportion of Vehicles Requiring Exchanges

August Saturday

vehicle	Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
1st exchange	0.01	0.04	0.036	0.06	0.07	0.32
2nd	-	0.01	0.014	0.03	0.04	0.13
3rd	-	-	0.006	0.02	0.03	-
4th	-	-	0.004	0.02	0.02	-
5th	-	-	-	0.01	0.01	-
6th	-	-	-	0.01	-	-
exchanges required as proportion of vehicles	0.01	0.05	0.06	0.15	0.17	0.45

October Weekday

vehicle	Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
1st exchange	0.005	0.06	0.14	0.23	0.25	0.27
2nd	-	0.02	0.055	0.12	0.15	0.05
3rd	-	-	0.025	0.08	0.10	-
4th	-	-	0.01	0.05	0.05	-
5th	-	-	-	0.04	0.02	-
6th	-	-	-	0.03	-	-
exchanges required as proportion of vehicles	0.005	0.08	0.23	0.55	0.57	0.33

Average day

vehicle	Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
1st exchange	0.005	0.05	0.10	0.17	0.19	0.24
2nd	-	0.02	0.04	0.09	0.11	0.03
3rd	-	-	0.02	0.06	0.07	-
4th	-	-	0.01	0.04	0.04	-
5th	-	-	-	0.03	0.01	-
6th	-	-	-	0.02	-	-
exchanges required as proportion of vehicles	0.005	0.07	0.07	0.41	0.42	0.27

Insitu Recharge Requirements

Currently available battery chargers generally need a transformer to either step the voltage down or up. For a 1 to 20kW charger they cost of the order of $£_{1975}$ 50 to 100 per kW. They are of such a size and weight that they could not be carried in vehicles. For the purposes of the analysis, and to demonstrate that a transformerless on board charger would be relatively cheap and simple, a simple recharge system was envisaged. The advantages of an on board charger are that recharging could be done anywhere there was a suitable supply. For example by cars at home or possibly in car parks or at parking meters. This would place no special requirements upon domestic supplies. The current required would be 30 to 40 amps and electric cookers are generally connected up by 60 amp cable. However difficulties would arise over a plug and socket able to carry this much current. It would have to involve compression of the conductors but given the potential mass market (approx. 20 million) should be reasonably cheap to produce.

The simple design of charger would have batteries with fully charged voltages just below mains voltage (240V). Charging would start with a peak power requirement and carry on until the battery reaches this voltage at which point there would be a very small power requirement. From a constant voltage source the charge entering a battery per second is an exponentially decaying function since the rate of flow depends upon the difference in voltage between source and battery. Due to the finite internal resistances of the source, battery and charger, the rate of charging approximates to a straight line function. If

I = peak current

V_s= supply voltage

t_c= charge time

E = energy stored in a fully charged battery

P = peak power rating of charger (= IV_s)

Then $E = 1/2\ I\ V_s\ t_c = 1/2\ P\ t_c$

$\therefore P = 2\ E/t_c$

To charge a 40kWh battery (E) in 8 hours (t_c) would require a charger with a 10kW rating (P). The charger power ratings for the batteries of each of the vehicles considered at various recharge times are shown in Table 2.12.

Table 2.12 Insitu Recharge Power Requirements

vehicle			Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
battery size		kWh	42	69	125	194	417	194
Recharge	4hr	kW	21	35	63	97	209	97
time	8hr	kW	11	17	31	49	104	49
of	12hr	kW	7	12	21	32	70	32

Further analysis of the systems effects of recharging are covered by the electricity system analysis (see below).

Battery Exchange Stations

In this part of the analysis the size of battery exchange infrastructure required to meet the previously found demand for battery exchanges and the costs of exchanges (net of taxes and profits) were estimated. The proportion of vehicles requiring exchanges (Table 2.11) were converted to numbers of exchanges required and the amount of energy dispensed on the three days was found (see Table 2.13).

Table 2.13 Battery Exchange Requirements

vehicle		Car	Van	Small Goods	Mid. Goods	Large Goods	Bus	Total
No of Vehicles million		26.4	2.0	0.36	0.11	0.63	0.09	
No of	Aug.Sat	264	100	22	17	107	41	551
Exchanges	Oct.weekday	132	160	83	61	359	30	825
'000/day[1]	Av.day	132	140	61	45	265	24	667
Energy	Aug.Sat	37	24	9	11	148	25	254
Delivered	Oct.weekday	18	38	33	38	495	18	640
TJ/day[2]	Av.day	18	33	25	28	366	15	485

notes: 1 No of vehicles * exchanges required as proportion of vehicles (see Table 2.11)
2 Battery size (see Table 2.12) * number of exchanges * average discharge factor (see Table 2.9)

The peak demand for batteries and for energy is on an October weekday due to goods vehicles.

A hypothetical exchange station was envisaged with two car/van bays and two goods/bus bays with fully automated exchange mechanisms for cars and semi-automated exchanges for goods. On the assumption that each exchange would take 5 minutes, the station could complete 24 car/van exchanges and 24 goods/bus exchanges per hour. With a 12 hour day the 360 thousand car/van exchanges on the August Saturday would require 1250 stations and the 530 thousand goods/bus exchanges on an October weekday would require 1840 stations on the assumption that there were no private exchange facilities. To allow for breakdowns and regional variations it was assumed that 2500 stations would be required.

The numbers of exchanges made on an average and a peak day by a typical station are shown in Table 2.14.

Table 2.14 Battery Stock Requirements

vehicle	Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Average day	53	56	24	18	106	10
peak day[1,2]	127	77	40	29	172	20

notes: 1 The peak day occurs at different times for the different vehicle types

2 Including a 20% safety margin

With an 8 hour recharge period and the maximum energy dispensed of 71 MWh per station (640 TJ/2500 stations, see Table 2.13) might require a peak charger capacity of 18MW. However this would only occur if all batteries were to start charging at the same time. It seems likely that the start of charge would be staggered over an average of perhaps four hours which would reduce the peak charger capacity required to 9MW. For the hypothetical station a 10MW charger was chosen. This would probably require its own substation.

The costs of running an exchange station were broken down into four components: operating costs, station capital charges, electricity costs, and battery capital charges. The first two were distributed over all users on an equal basis per exchange and the last two were attributed to each vehicle individually. Operating costs were taken to be $£_{1975}$ 15,000 for staff (forecourt attendant, cashier, manager and three mechanics) plus $£_{1975}$ 25,000 for rates, station maintenance etc. Station capital cost estimates are shown in Table 2.15, and are comperable to those given by Weeks (1978).

Table 2.15 Exhange Station Capital Costs

	$£'000_{1975}$
Site (650 sq m @ £20/sq m)	13
Buildings (125 sq m @ £175/sq m)	22
Equipment:	
chargers and electricity supply (10MW @ £10/kW)	100
exchange equipment	150
workshops	100
Total	385

The capital costs of batteries would be quite high with car batteries of the order of $£_{1975}$ 840 and large goods at $£_{1975}$ 8,300 (approx. £20/kWh, see Weeks 1978, p8). To avoid the necessity for transfer payments on each battery exchange the batteries would have to be hired. The annual hire charges for various interest rates are shown in Table 2.16.

Table 2.16 Annual Battery Hire Charges

vehicle		Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Annual kilometres		15800	25500	27200	38700	55555	37777
Battery life[1]	years	20	12.5	11.8	8.3	5.8	8.5
Size of Battery	kWh	42	69	125	194	417	194
Capital Cost[2]	$£_{1975}$	840	1380	2500	3880	8340	3880
Annaul hire charge[3] $£_{1975}$/yr							
	5	67	151	286	583	1692	571
Interest	7	79	169	318	632	1799	621
Rate	10	99	198	370	710	1964	699
%	15	134	251	464	848	2252	837
	20	172	307	566	995	2556	985

notes: 1 @ 320 000 km (Anon 1980)
2 @ £20/kWh (Weeks 1978)
3 repayment = Capital * $r(1+r)^n/(1+r)^n-1$

The total annual capital charges for the station battery stocks are shown in Table 2.17.

Table 2.17 Battery Stock Capital Charges per Station

vehicle		Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
No of batteries		127	77	40	29	172	20
Annual	5%	8.5	11.6	11.4	16.9	291.0	11.4
Capital	10%	12.6	15.2	14.8	20.6	337.8	14.0
Charges	20%	21.8	23.6	22.6	28.9	439.6	19.7
£'000$_{1975}$							

Finally the fuel costs of recharging are shown in Table 2.18.

Table 2.18 Battery Recharge Average Fuel Costs

vehicle		Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Battery size	kWh	42	69	125	194	417	194
Av discharge factor[1]		0.93	0.95	0.91	0.89	0.92	0.87
Cost per exchange[2]	£$_{1975}$	0.55	0.92	1.59	2.42	5.37	2.36

notes: 1 From Table 2.9
2 @ 1.4 p/kWh

Because battery recharging can be used to fill the troughs on the electricity system (see electricity system analysis below, 2.3.11) it was assumed that there will be a discount from the average cost of 2.1 p/kWh (Table 2.34) to 1.4 p/kWh. The total of all four cost elements for each vehicle type are shown in Table 2.19.

Table 2.19 Estimated Average Cost of Exchanges (net of profits and taxes)

vehicle	Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Station Capital (10%-10yrs) Charges[1]			0.64			
Operating costs[1]			0.12			
Battery Capital Charges (10%)	0.65	0.74	1.69	3.14	8.73	3.84
Fuel costs[2]	0.55	0.92	1.59	2.42	5.37	2.36
Total Cost £/exchange	1.96	2.42	4.04	6.32	14.86	6.96

notes: 1 equal cost per exchange (Annual cost/ av exchanges per day (=267)/ 365)
2 From Table 2.18

Liquid Fuelled Stations

As with battery exchange stations estimates were made of the required number of filling stations and the cost of dispensing fuel (net of profits and taxes). In this case the analysis was easier because it was assumed that the liquid fuels derived from coal could be handled, stored and dispensed in the same way as petrol and diesel are today. Having examined recent trends in the average size of filling stations (210,000 gal/yr in 1975, see Figure 2.8) it was estimated that 500,000 gal/yr stations would be typical for 2025.

A further simplifying assumption was made that all fuel would be dispensed at filling stations to obviate the need to estimate quantities which will be privately handled at Goods and Bus owners own depots. For the 1526 PJ/yr (Table 2.8), which is $9.6 * 10^9$ gallons per year, there would need to be aproximately 23,000 stations.

Estimates of filling station capital costs are given in Table 2.20 for a typical 500,000 gal/yr station.

These estimates were based upon Weeks (1978). The annual station running costs are given in Table 2.21.

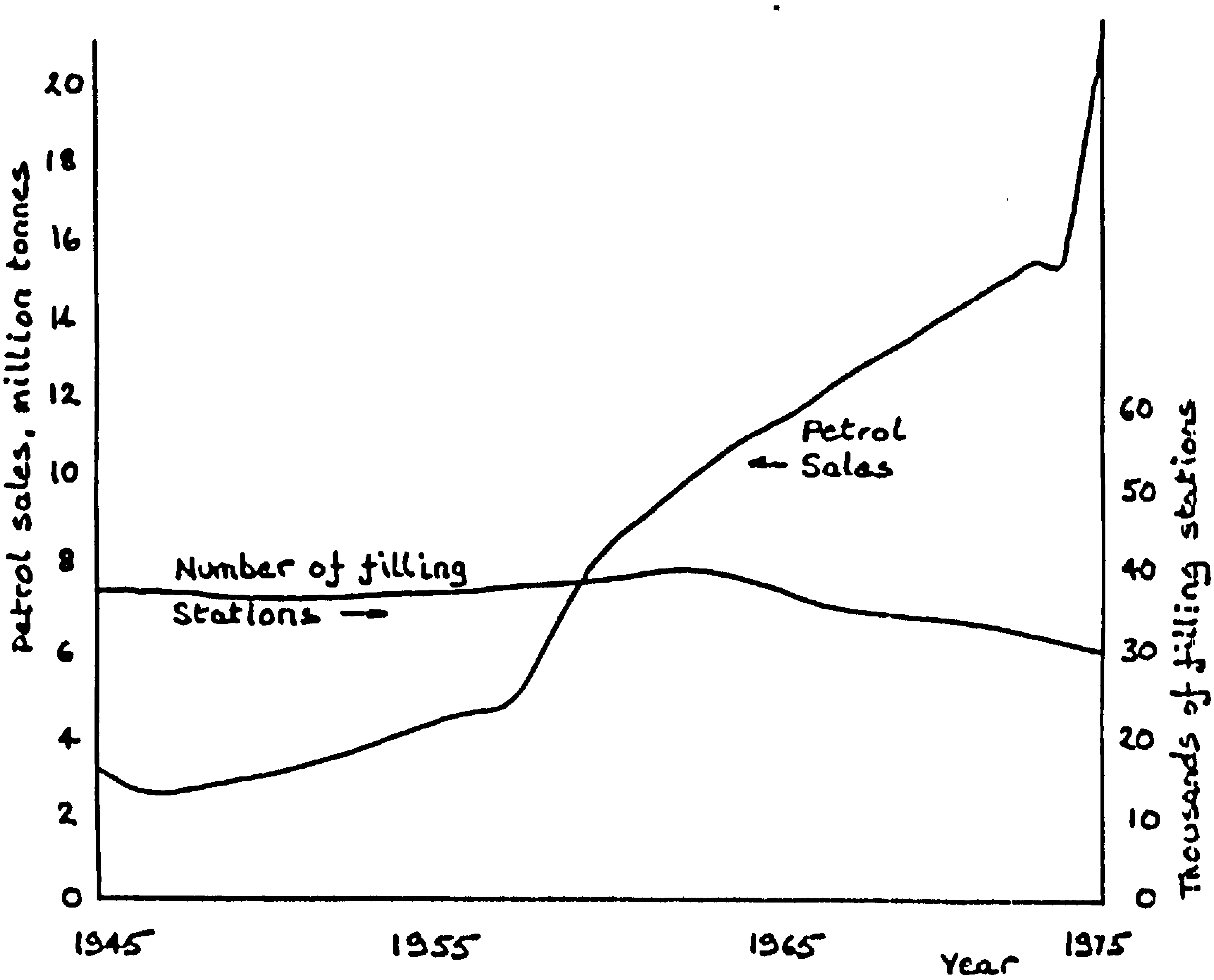


Figure 2.8 UK Petrol sales and numbers of filling stations

Table 2.20 Filling Station Capital Cost

(for 500,000 gal/yr self service station)

	$£'000_{1975}$
Land	14
Buildings and Services	88
Tanks and Pumps	12
Total	114

source: after Weeks (1978)

The total cost of $£_{1975}$ 38,000 per year is equivalent to 8p/gallon.

Table 2.21 Average Filling Station Running Cost

(for 500,000 gal/yr self service station)

	£'000$_{1975}$/yr
Capital Charges (10%-10yrs)	19
Labour	13
Rates, Insurance, and other costs	8.6
Total	38
Cost (p/gallon)	7.6
(£/GJ)	0.48

source: after Weeks (1978)

UK Primary energy supply

Following an analysis similar to that in the FTF study, the primary energy availability shown in Table 2.22 was estimated.

Table 2.22 Projected UK Primary Energy Supply for 2025

	mtce/yr
Coal	200-250
Oil	0
Gas	0
Primary Electricity	
Nuclear	211-422
Waves	50
Solar	40

based on: Department of Energy (1976),
National Coal Board (1974),
National Coal Board (1976)

It was assumed that following the decline of north sea oil and gas the UK will remain energy self sufficient so for 2025 these would be the only supplies available.

Useful Energy Demand Projections

The two road transport fuel scenarios were compared in terms of national energy demand. This was found by making useful energy demand projections and then meeting these demands by allocating fuels up to limits imposed by primary energy availability.

The projections of useful energy were taken from the FTF study. They were for the six sectors: Domestic, Public Services, Other Services, Agriculture, Industry and Transport (other than road). Road transport was dealt with separately as noted above. The projections were made by relating the historic demand for useful energy to activity levels for each sector. For domestic the activity level used was houses and for the remainder the contribution each sector makes to GDP (net output). The activity levels were then projected to 2025 to get useful energy demands. The growth rates for GDP assumed were for 1975 to 2000 2% and for 2000 to 2025 1.5%. These projections of the historic relationship between activity level and useful energy take no account of likely reductions due to conservation so percentage reductions were made as shown in Table 2.23.

<u>Table 2.23 Useful Energy Demand Projections for 2025</u>

Sector		Domestic	Public Services	Other Services	Agricul- ture	Ind- ustry	Trans- port[1]
Activity Indicator		Number of dwellings	G.D.P. Contribution (net output)				
Gradient							
Useful energy per unit activity GJ/dwelling or $MJ/£_{1970}$		58	30	10	30	80	45
Intercept at zero activity	PJ	0	50	80	-10	0	20
Number of dwellings or Proportion of G.D.P.[2]		30	0.23	0.38	0.03	0.33	0.03
Useful energy demand without Conservation	PJ	1740	930	560	100	3410	220
Useful energy demand Conservation saving	%	25	25	25	-	28	15
Useful energy demand with Conservation	PJ	1300	700	420	100	2500	190

source: Chapman, Charlesworth and Baker (1976)
notes: 1 Except for Road Transport
2 GDP growth rates assumed 1975-2000 2.5% pa and 2000-2025 1.5 % pa, giving GDP in 2025 of £'000 million 127.8

Fuel Allocations

Using the same procedure as used in the FTF study, fuels were allocated first to Road Transport then to fixed demands and finally to flexible demands. The breakdown of useful energy to fixed and flexible demands is shown in Table 2.24.

Table 2.24 Fixed and Flexible Useful Energy Demands for 2025

PJ

Sector		Domestic	Public Services	Other Services	Agricul-ture	Ind-ustry	Trans-port[1]
Fixed	Coal	-	-	-	-	1000	-
	Gas	100	-	-	-	-	-
demand	Liquid	-	-	-	60	-	130
	Solar	280	150	100	-	-	-
for	Electricity	330	210	126	-	750	60
Flexible demand		590	340	194	40	750	-
Total useful energy demand		1300	700	420	100	2500	190

source: Chapman, Charlesworth and Baker (1976)

notes: 1 Except for Road Transport

The conversion efficiencies of Primary energy to fuel and fuel to useful energy are shown in Tables 2.25 and 2.26.

Table 2.25 Primary to Delivered Energy Conversion Efficiencies

	Coal	Coal to				Nuclear waves[1]		Solar
		Liquid	Gas	Electricity	Batteries	Electricity	Batteries	Heat[2]
Extraction	0.95	0.95	0.95	0.95	0.95			
Conversion	-	0.65	0.70	0.35	0.35			
Transmission	-	0.90[3]	0.98	0.90	0.90			
Battery charging	-	-	-	-	0.80			
Overall efficiency	0.95	0.56	0.65	0.30	0.24	0.30	0.24	0.65
Fuel per unit of primary energy PJ/mtce	14.66 27.36	liquid 1.47 gas	18.72	8.64	6.91	8.64	6.91	18.72

source: Chapman, Charlesworth and Baker (1976)

notes: 1 on a coal equivalent basis
2 on a gas equivalent basis
3 refining and delivery

Table 2.26 Delivered to Useful Energy Conversion Efficiencies

Fuel	Coal	Liquid	Gas	Electricity
Enduse				
Heat	-	-	0.7	1.0
Light, work	-	-	-	1.0
Transport	-	0.2	-	-
Agriculture	-	0.3	-	-
Industrial Carbon	0.7	-	-	-

source: Chapman, Charlesworth and Baker (1976)

The order of allocation was:

(a) allocate fuel(s) to road transport (see Table 2.27)

(b) allocate fuels to fill the fixed demands: industrial carbon, gas to the domestic sector, liquid fuels for agriculture and other transport and electricity in all sectors except agriculture.

(c) allocate by-product gas (from liquid fuel production) then gas from coal (up to a nominal coal limit of 250 million tonnes) to fill flexible demands and finally to fill any remaning demands with electricity.

Table 2.27 Primary Energy Demand for Road Transport

Vehicles	Liquid fuelled		Electric			
			electricity		heat	
	delivered PJ/yr	primary mtce/yr	delivered PJ/yr	primary mtce/yr	delivered PJ/yr	primary mtce/yr
Cars	895	61	188	27	38	2.5
Vans	115	8	31	4	4	0.3
Goods	484	33	228	33	4	0.3
Busses	32	2	12	2	1	0.1
Total	1526	104	459	66	47	3.2

In the electric vehicle scenario (Table 2.28) it was possible to meet all flexible demands from coal.

Table 2.28 Primary Energy Allocation: Electric Vehicle Scenario

mtce/yr

Sector	Coal	Coal Liquid	Coal Gas	Solar	Elec-tricity	Total
Domestic	-	-	[6][1]47	21	38	106
Public Services	-	-	26	11	24	61
Other Services	-	-	15	8	15	38
Agriculture	-	14	-	-	5	19
Industry	52	-	57	-	87	196
Road Transport	-	3	-	-	66	69
Other Transport	-	44	-	-	7	51
Coal for electricity	0	-	-	-	0	0
Total		258		40	242	540

notes: 1 by-product gas which is not counted in total demand

However for the liquid fuelled vehicle scenario (Table 2.29) there were only 16 million tonnes of coal remaining after fixed demands had been met. This was reserved for electricity production (see below), and the flexible demands were met from electricity.

Table 2.29 Primary Energy Allocation: Liquid Fuelled Vehicle Scenario

mtce/yr

Sector	Coal	Coal Liquid	Gas	Solar	Electricity	Total
Domestic	-	-	[16][1]	21	94	115
Public Services	-	-	-	11	64	75
Other Services	-	-	-	8	37	45
Agriculture	-	14	-	-	5	19
Industry	52	-	-	-	174	226
Road Transport	-	104	-	-	-	104
Other Transport	-	44	-	-	7	51
Coal for electricity	44	-	-	-	-44	0
Total		258		40	337	635

notes: 1 by-product gas which is not counted in total demand

Electricity System

A half hourly electricity demand model (see Appendix 4) was used to examine the effects of load control by the grid system operators and of a system store on the average load factor and the installed capacity. By load control is meant any method of interrupting a load so that it fills in the trough in each day's demand. This can be achieved in any of several ways such as ripple control or logic devices in each appliance (Salter 1977). On the assumption that the latter would be used, any load to which load control is applied is refered to as a 'logic load'. The electricity model was also used to determine the nuclear and coal fired capacities required.

The model used as input the previously found electricity demands from each sector. These are shown in Table 2.30.
The model has three main categories of demand (Domestic, Commercial and Industrial) to which can be added battery recharging and off peak heating. These two additional loads are potentially 'off-peak' loads and can be given a daily load pattern similar to today's off-peak domestic space heating load or can be treated as a logic load. For the liquid fuelled vehicle scenario loads larger than those in the electric vehicle scenario were taken to be space heating and suitable for treatment as potential 'off-peak' loads (see Table 2.30).

Table 2.30 Electricity Demands

Scenario	Electric vehicles				Liquid fueled vehicles			
	mtce		GWyr[1]		mtce		GWyr[1]	
Sector			"on-peak"	"off-peak"			"on-peak"	"off-peak"
Domestic		38	12	-		94	12	17
Services:								
Public	24}				64}			
Other	15}				37}			
Agriculture	5}	51	15	-	5}	113	15	18
Other Transport	7}				7}			
Industry		87	26	-		174	26	26
Road Transport		66	-	20		-	-	-
Total "off-peak"				20				61

notes: 1 With 95% mining & 35% generating efficiency 1 mtce will produce $28.8*10^{15}*0.95*0.35/(3.6*10^{12}*8760)$ = 0.304 GWyr of electricity at the power station.

For the electric vehicle scenario the results of running the model with and without a system store and with and without battery charging on logic load are illustrated in Figure 2.9 and Table 2.31.

Table 2.31 Electricity System for Electric Vehicle Scenario

	Without logic load		With logic load	
	Without System Store	With System Store	Without System Store	With System Store
Size of System Store GWh	-	269	-	15
Maximum output of store GW	-	53	-	5
Average load on System GW	73	75	73	73
Maximum load on System GW	123	80	83	79
Load factor %	59	94	88	93

With battery charging on the 'off-peak' shape of load, charging would cause the system peak of 123GW, so this case is inconsistent. With charging on logic load the maximum load on the system would be 83GW which could be reduced to 97GW with a system store of 15GWh.

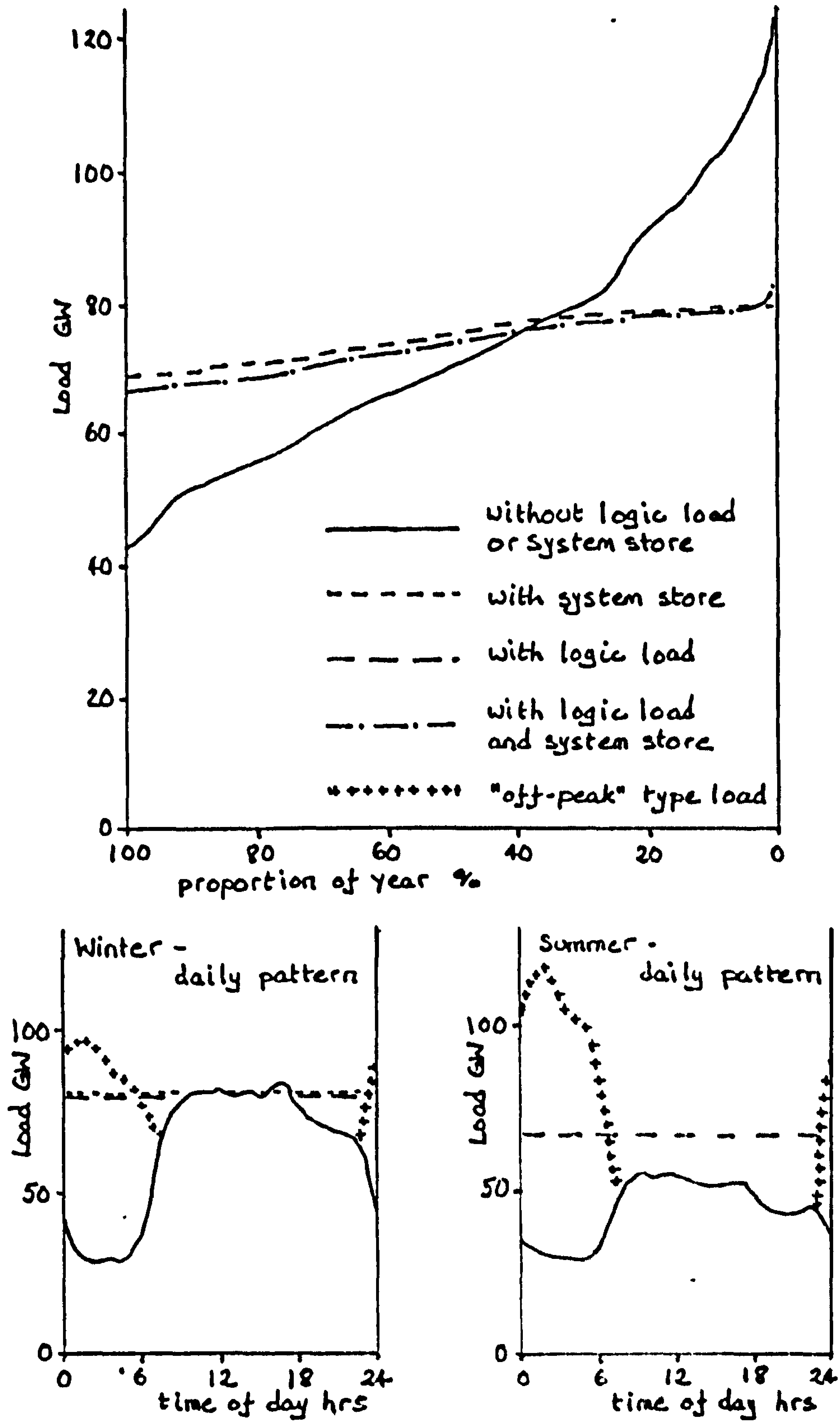


Figure 2.9 Load duration and load patterns for electric vehicle scenario

For the liquid fuelled vehicle scenario the results of running the model are illustrated in Figure 2.10 and Table 2.32.

Table 2.32 Electricity System for Liquid Fuelled Vehicle Scenario

	Without logic load		With logic load	
	Without System Store	With System Store	Without System Store	With System Store
Size of System Store GWh	-	1765	-	84
Maximum output of store GW	-	336	-	10
Average load on System GW	114	122	114	115
Maximum load on System GW	551	215	199	199
Load factor %	21	57	57	58

As with the electric vehicles an 'off-peak' shape to the heating load would produce a very large peak of over 500GW. Consequently such 'off-peak' heating will not exist. Of the four cases the lowest maximum load is for the logic load heating at 199GW. The introduction of a system store would have no effect on the maximum load and would not be worthwhile.

The optimum supply systems for the two scenarios are assumed to be nuclear plants only with system storage for the electric vehicle scenario and a mixture of coal fired and nuclear plant with no system storage for the liquid fuelled vehicle scenario. As previously noted there is a limited supply of coal for the second case and it would all be used by 70GW of coal plant. The installed capacities required for the two scenarios are shown in Table 2.33.

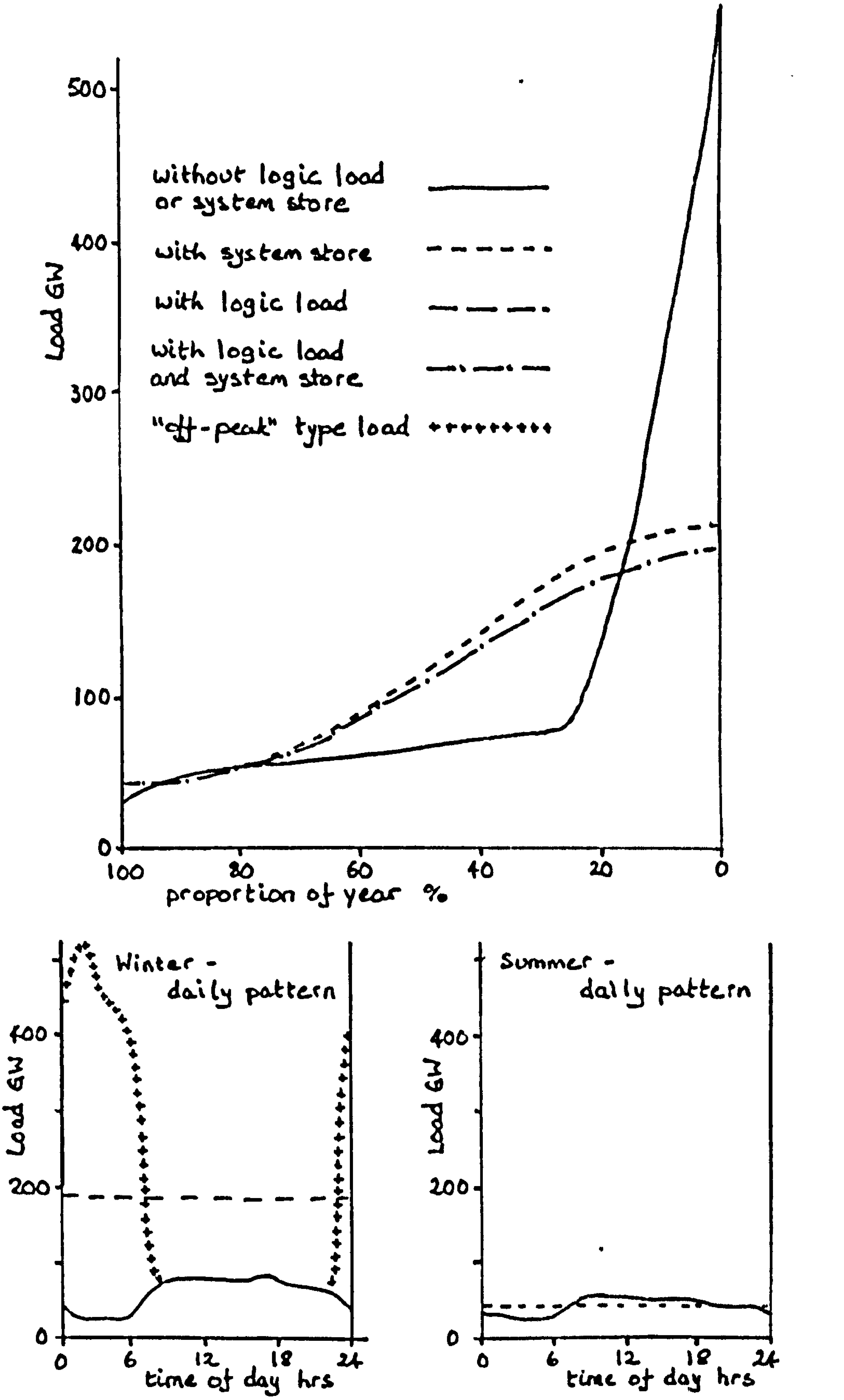


Figure 2.10 Load duration and load patterns for liquid fuelled vehicle scenario

Table 2.33 Electricity System Installed Capacity

Scenario		Electric Vehicles	Liquid Fuelled Vehicles
Maximum load	GW	79	199
Planning margin (20%)	GW	16	40
Installed capacity	GW	95	239
Store size	GW	5	-
Coal fired plant	GW	-	70
Nuclear plant	GW	95	169
Electricity generated			
Coal	GWyr/yr	-	13[1]
Nuclear	GWyr/yr	73	101
Average plant load factors			
Coal	%	-	19
Nuclear	%	77	60

notes: 1 44 mtce/yr will provide 44 * 0.304 = 13 GWyr/yr
(see Table 2.30, note 1)

Fuel Costs

Following the fuel cost estimates made in the FTF study, estimates were made of electricity, gas and liquid fuel costs as shown in Table 2.34. For nuclear generated electricity two costs were derived which correspond to the average plant load factors for the two scenarios. For coal based fuels two costs were calculated corresponding to coal costs of 15 and 30 £ 1975/tonne. The fuel costs can be converted to a primary energy cost by multiplying by the primary energy to fuel conversion efficiency. For example with coal at £30/tonne, gas costs 0.838 p/kWh or 2.33 £/GJ this is equivalent to 0.7*2.33 = 1.631 £/GJ of primay energy = 47.0 £/mtce. Of the total cost of gas 30/47 (64%) is due to the cost of coal and the remainder is due to capital, depreciation, labour and overhead charges.

Table 2.34 Fuel Cost Estimates for 2025 (1975 price levels)

		Electricity				Gas from		Liquids from	
		Nuclear		Coal		Coal		Coal	
Capital cost	(£/kWso)	500		150		80		60	
Conversion efficiency	%	35		35		70		65	
Load factor	%	77	60	19		50		80	
Coal cost	£/tonne	-	-	15	30	15	30	15	30
Works cost	p/kWh								
Capital	(10%-20yrs)	0.871	1.117	1.059	1.059	0.215	0.215	0.101	0.101
Fuel		0.400	0.400	0.536	1.071	0.268	0.536	0.288	0.577
Other		0.100	0.100	0.150	0.150	0.065	0.065	0.100	0.100
Ex-works cost	p/kWh	1.371	1.617	1.745	2.280	0.548	0.816	0.489	0.778
Other charges	p/kWh								
Capital-transmission		0.450	0.450	0.343	0.343	0.040	0.040	-	-
refining		-	-	-	-	-	-	0.240	0.240
Overheads		0.250	0.250	0.250	0.250	0.250	0.250	0.150	0.150
Total fuel cost	p/kWh	2.071	2.317	2.338	2.873	0.838	1.106	0.879	1.168
	£/GJ	5.75	6.44	6.49	7.98	2.33	3.07	2.44	3.24
Primary energy cost	£/mtce	58.0	64.9	65.4	80.4	47.0	61.9	48.7	60.7

source: after Chapman, Charlesworth and Baker (1976)

Primary Energy Demands and Costs

The primary energy demands for the two scenarios are shown in Table 2.35.

Of the two, the electric vehicle scenario has the lower primary energy demand of 540 mtce, compared with 635 mtce for the liquid fuelled vehicle scenario. Also shown in Table 2.35 are the total costs of the energy. With coal at both 15 and 30 £/tonne the electric vehicle scenario costs substantially less than the liquid fuelled vehicle scenario.

Table 2.35 Total Annual Energy Demands and Costs

Scenario		Electric Vehicles Primary energy mtce	Cost £ million		Liquid Fuelled Vehicles Primary energy mtce	Cost £ million	
Coal cost	£/tonne	-	15	30	-	15	30
Coal as	Coal	52	780	1560	52	780	1560
	Liquid	61	2788	3703	162	7403	9833
	Gas	145	6815	8976	-	-	-
	Electricity	-	-	-	44	2878	3538
	Total	258	10383	14239	258	11061	14931
Solar[1]		40	1880	2476	40	1880	2476
Primary Electricity		242	14036	14036	377	21871	21871
Total		540	26299	30751	635	34812	39278
Total Electricity		242	14036	14036	381	24749	25409

notes: 1 on a gas equivalent basis

Fuel Cost per Vehicle

There are four components to the cost of fuel for electric vehicles. These are:

(a) Cost of electricity used to recharge vehicle battery whilst it is still in the vehicle (insitu recharging)

(b) Cost of battery exchanges

(c) Battery hire cost

(d) Heating fuel cost.

The previous analysis of vehicle journey patterns was used to find the total number of battery exchanges on an average day. This was used to find the average number of exchanges required per vehicle. This was then used to find the number of kilometers which are run on insitu recharging. These calculations and the resultant costs are shown in Table 2.36.

Table 2.36 Electric Vehicle Annual Fuel Costs

Vehicle		Car	Van	Small Goods	Mid. Goods	Large Goods	Bus
Av annual kilometers		15800	25500	27200	38700	55555	37777
Av number of battery exchanges[1]		2	26	62	149	153	97
Cost per exchange[2]	£/yr	1.96	2.42	4.04	6.32	14.86	6.96
Annual exchange cost	£/yr	4	63	250	942	2274	675
Insitu recharge km[3]		15240	16140	14180	13370	18835	25167
Av fuel consumption	MJ/km	0.45	0.60	1.82	3.30	5.63	3.39
Insitu recharge cost[4]	£/yr	27	38	100	172	412	332
Battery hire cost[5]	£/yr	99	198	370	710	1964	699
Heating fuel	MJ/km	0.09	0.08	0.09	0.09	0.09	0.15
Heating cost[6]	£/yr	5	7	8	11	16	18
Total cost	£/yr	135	306	728	1835	4666	1724

notes:

1 Average number of battery exchanges per year = 365 * ("Average day" total number of exchanges, see Table 2.13) / total number of exchanges

2 From Table 2.19

3 Insitu recharge km = Average annual km − number of exchanges * exchange range (see Table 2.9)

4 Electricity at 1.4 p/kWh (3.89 £/GJ)

5 It is assumed all batteries are hired rather than owned to remove need for large transfer payments on exchanging a battery. Battery hire costs are at 10 % (see Table 2.16)

6 Liquid fuel at 3.24 £/GJ

The fuel cost for liquid fuelled vehicles are simply the product of annual range, fuel consumption and unit fuel cost. These are shown in Table 2.37.

Also shown in this table are average annual fuel costs for each vehicle. These were found using the normalised populations (Table 2.5) as weighting factors.

Comparisons of fuel costs for vehicles run on the two fuels are shown in Figures 2.11 to 2.16.

Table 2.37 Liquid Fuelled Vehicle Fuel Costs

Vehicle group		Ann Av kms '000 km/yr	fuel consum-ption MJ/km	Fuel GJ/yr	Annual Fuel cost £/yr	norm-alized popul-ation	Av Annual Fuel cost £/yr
Car	-1		1.6	25.3	82	0.15	
by	1-1.5		2.0	31.6	102	0.50	
engine	1.5-2	15800	2.5	39.5	128	0.32	110
size	2-3		3.2	50.6	164	0.02	
litre	3+		3.8	60.0	195	0.01	
Van by	-0.8		1.8	45.9	149	0.25	
ULW	0.8-1	25500	1.9	48.5	157	0.24	184
ton	1-1.5		2.6	66.3	215	0.51	
Goods	1.5-2	27200	4.1	112	361	0.10}	466
by	2-3	27200	5.8	158	511	0.23}	
ULW	3-5	38700	6.7	259	840	0.10	840
ton	5-8	43000	10.0	430	1393	0.32}	2244
	8+	71700	12.8	918	2974	0.25}	
Bus	8-32		5.8	219	710	0.12	
by	32-48	37777	8.5	321	1040	0.28	1155
seats	48+		10.6	400	1297	0.60	

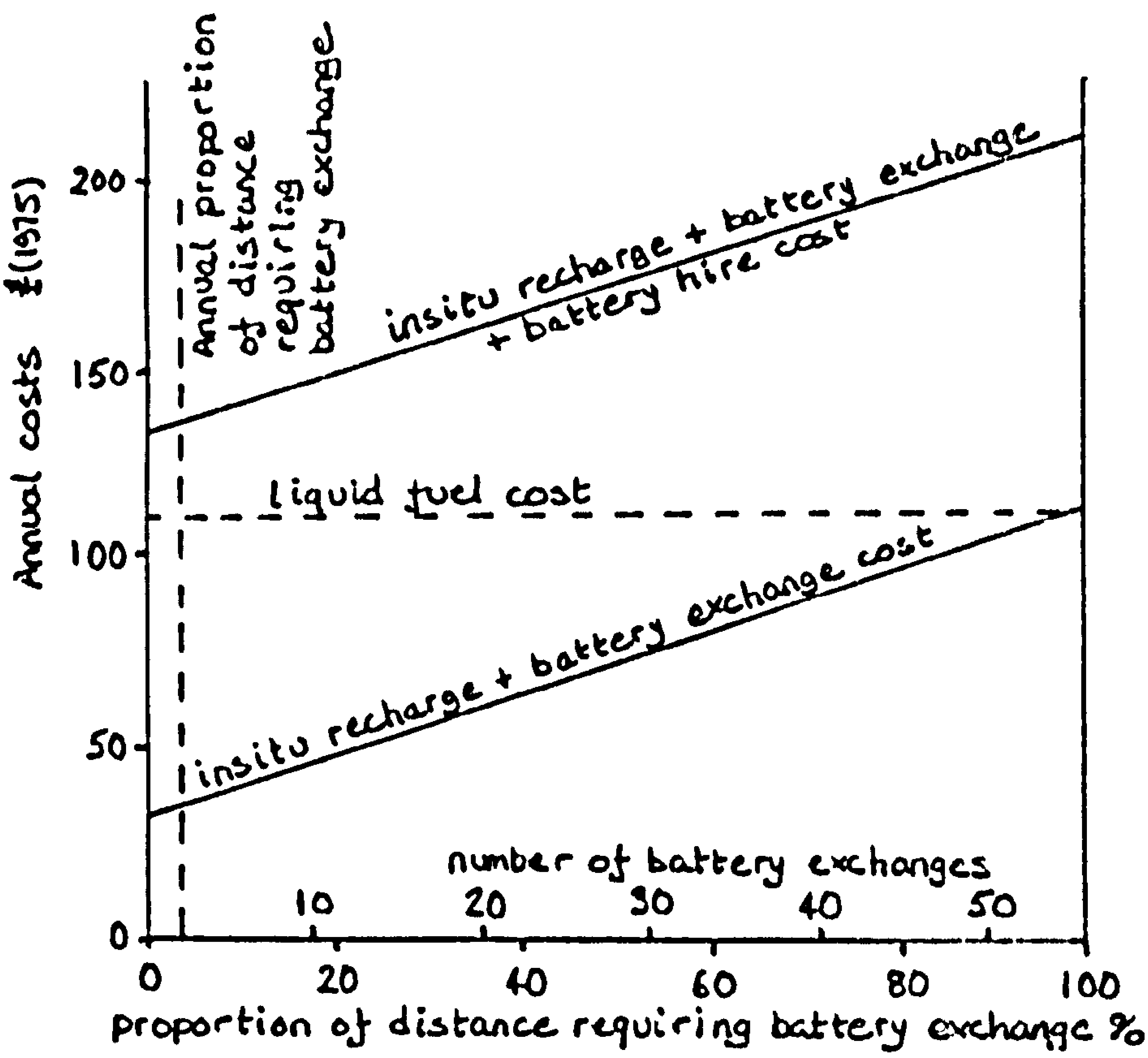


Figure 2.11 Comparison of fuel costs for cars

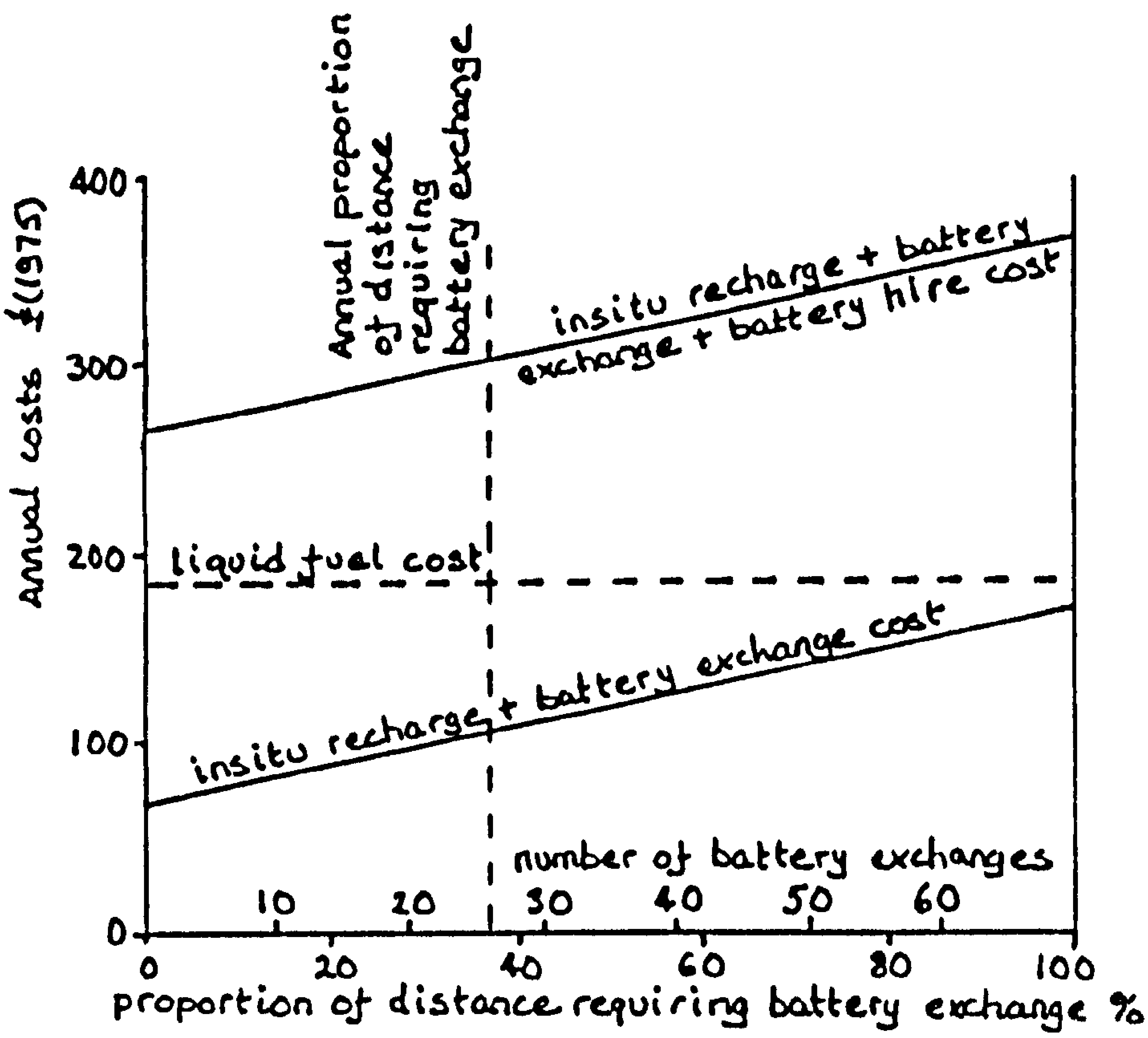


Figure 2.12 Comparison of fuel costs for vans

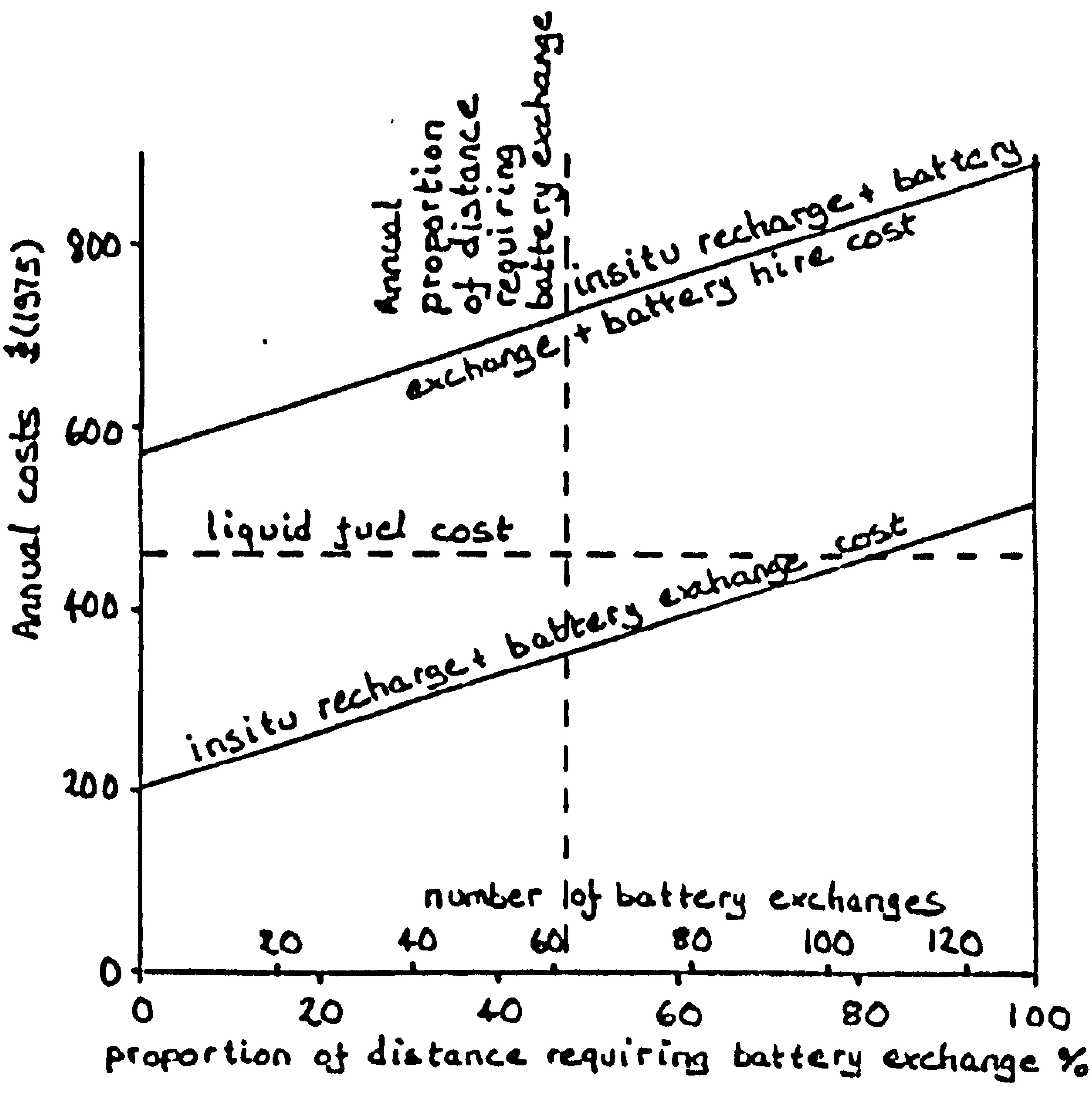


Figure 2.13 Comparison of fuel costs for small goods

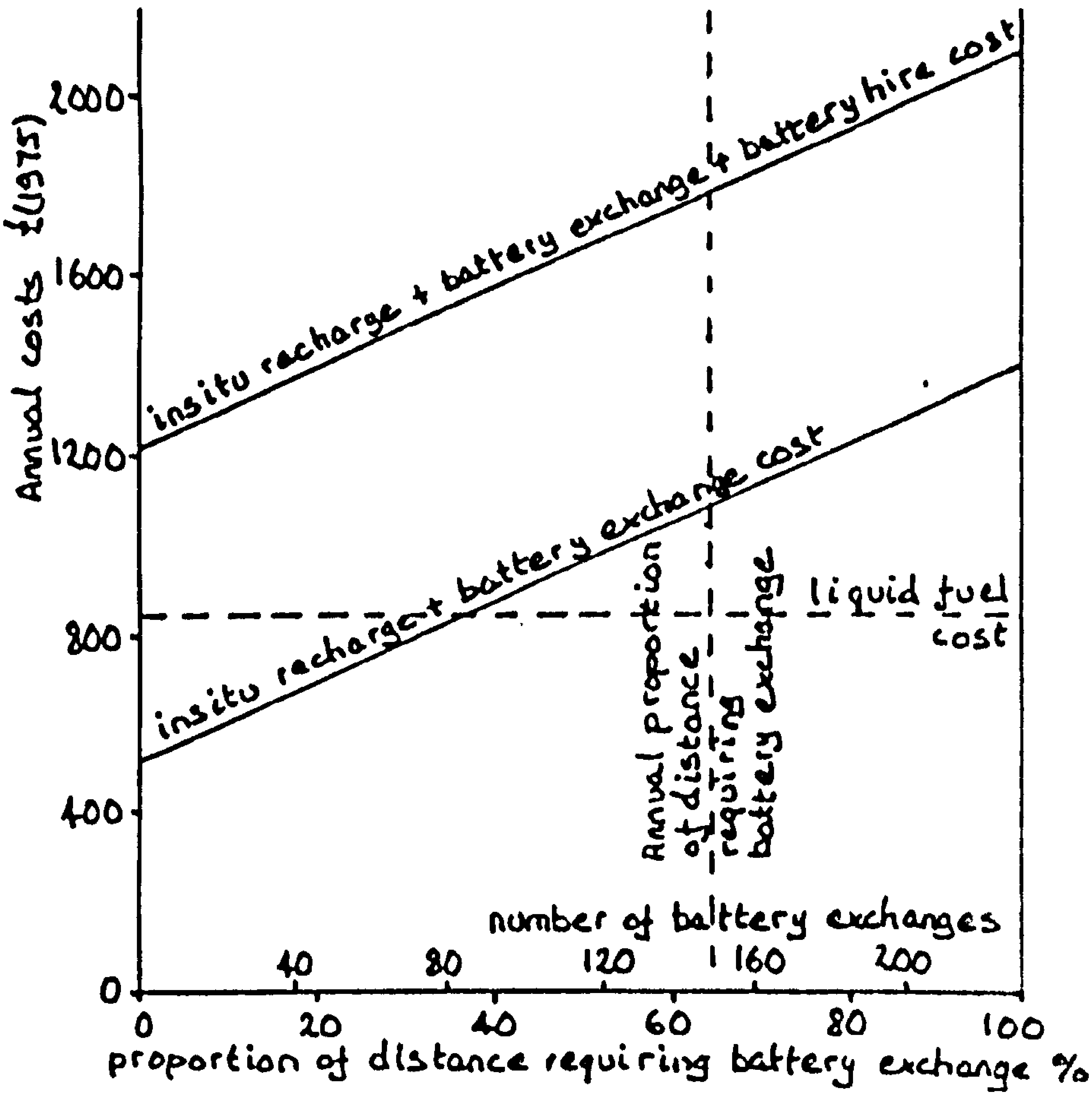


Figure 2.14 Comparison of fuel costs for middle goods

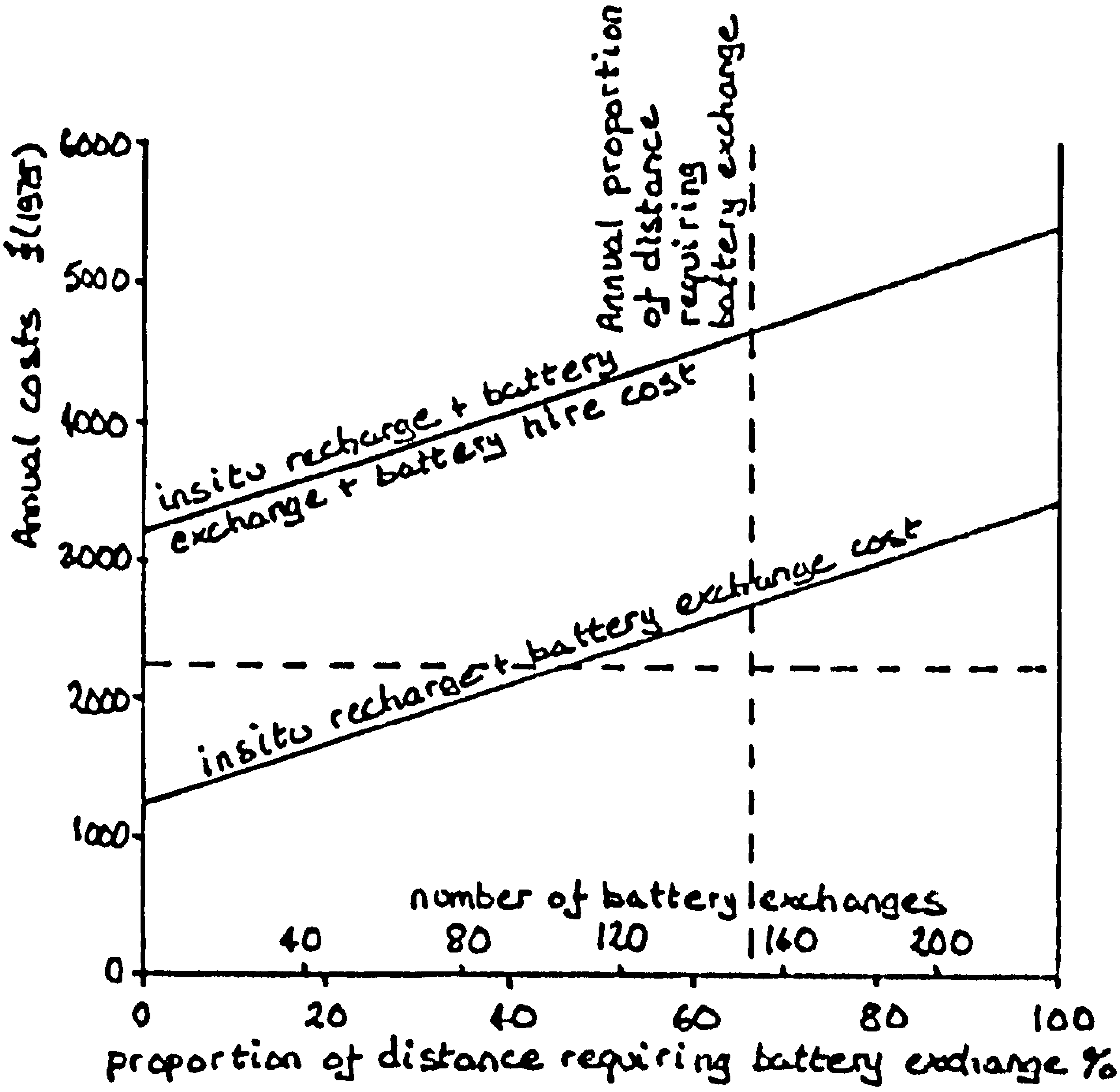


Figure 2.15 Comparison of fuel costs for large goods

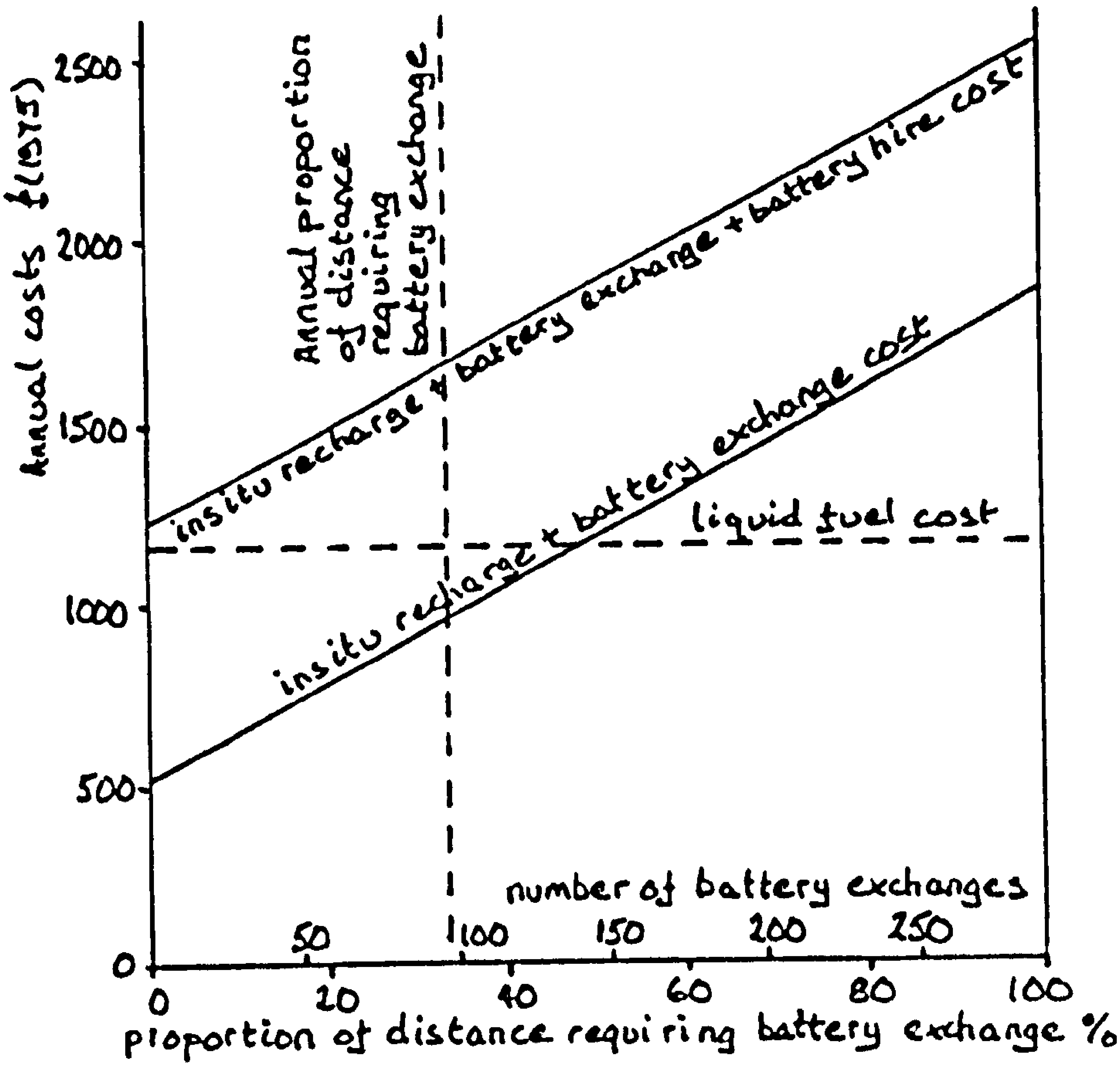


Figure 2.16 Comparison of fuel costs for busses

2.4 Conclusions to the VRI study

The VRI study arose out of the earlier FTF study by Chapman, Charlesworth and Baker (1976) which examined the availability and suitability of the transport fuels most likely to be available to the UK over the next 50 years. The study re-examined the analyses contained in the earlier study and also examined the refuelling infrastructures required for an all electric road vehicle fleet or an all liquid fueled road vehicle fleet. The electric vehicle infrastructure envisaged would allow electric vehicles to fill the same pattern of use as liquid fuelled vehicles.

In the VRI study it was shown that electric vehicles using a high energy density battery can be designed to have roughly comparable performance (top speed, acceleration, hill climbing ability etc.) with an internal combustion engine vehicle. It was found that the energy demands for heating electric vehicles, often neglected in analyses of this type, make little difference to the overall energy requirement for an electric vehicle (at least for use in the UK).

In contrast to the FTF study which considered only electric cars and vans, a comparison was made between a scenario in which the whole road vehicle fleet was electric with one in which all road vehicles were run on liquid fuels derived from coal. This further electrification reinforces the primary energy advantages of the electric vehicle scenario.

The study involved an investigation of two refuelling methods possible with electric vehicles, namely:

(a) Insitu recharging - recharging the battery while it is still in the vehicle; which can be accomplished when and where the vehicle is garaged or parked

(b) Battery exchange - exchanging a charged battery for a discharged one; which requires specialised equipment.

These two refuelling methods allow the major disadvantage (limited range) of electric vehicles to be overcome. The analysis of vehicle design and performance together with the data on vehicle use patterns lead to an estimate that approximately 2500 battery exchange stations would be required to meet the peak day demand for batteries (August Saturday for cars and an October weekday for goods vehicles). It was assumed that exchange stations would be used by all road users. No consideration was given to what fraction of the vehicle fleet might be serviced by private battery exchange stations. Goods vehicle exchanges played a large part in determining the size of the exchange system since they were responsible for the peak in demand for energy dispensed.

For the liquid fuelled vehicle scenario it was estimated that approximately 23,000 filling stations would be required.

It was found that without battery exchange (and so the need for hiring batteries) all electric vehicles had a lower fuel cost than the corresponding liquid fuelled vehicle. However with an average number of exchanges only the electric car had a lower fuel cost (including battery hire) than the corresponding liquid fuelled vehicle.

It is however worth questioning the wisdom of constraining the battery electric vehicle to follow the same pattern of use as today's liquid fuelled vehicle. In reality the vehicles themselves will generate their own use patterns. This may involve a renucleation of the industrial, shopping, and living area s in cities and towns and/or a mixed mode approach to long distance travel. Whatever does happen in the future it is almost impossible to predict with any degree of accuracy. Any approach to forecasting the exact patterns of use followed by electric vehicles in 2025 is likely to be much more subjective than the approach adopted in the VRI study. It is also worth noting that the only cost comparison made between the vehicles is of fuel cost. Also there was no consideration of alternative ways of overcoming the range limitaions of electric vehicles such as the use of a mobile generator for use on long journeys (Lee and Corbett 1979).

Finally the systems effects associated with the widespread use of electric vehicles were considered. All the analyses were for a time in the future when it is assumed that the UK will be without indigenous natural oil or gas. The only fossil fuel available will be coal, which can be converted into a wide range of other fuels including synthetic natural gas and a liquid fuel for road transport.

In the liquid fuelled vehicle scenario the fixed demands for coal (that is demands which are not easily substitutable) are so large (250 Mtpa) that they equal the assumed maximum output of the UK coal industry. As a result all the flexible energy demands (ones which are easily substitutable), such as space heating, have to be met using electricity. In the electric vehicle scenario the fixed demands for coal were much smaller (in particular less liquid fuels and no coal for peak following electricity stations). As a result gas from coal could be used to meet all the flexible energy demands, giving a total coal demand of 250 Mtpa. It is much more efficient in primary energy terms to use gas from coal for space heating than electricity. Consequently the electric vehicle scenario shows a very large saving in both primary energy and running cost over the liquid fuelled vehicle scenario. The electric vehicle scenario also required a much smaller installed electricity generating capacity and the load factor on this capacity was such that it could be totally nuclear. Consequently the systems effects are very much in favour of the electric vehicle.

2.5 Further Research

There are four main areas in which further research may be fruitful. These are the range requirements of vehicles, further developments of the computer models used, the development of more scenario s and practical work.

Range Requirements

The range identified as being important in the VRI study was the daily range of a vehicle since most vehicles are not used for at least eight hours overnight which is ample time to recharge batteries. There are two distributions of daily ranges which are of interest. The first (that for which estimates were made in the VRI study) is of the ranges of all vehicles (of a given type such as cars) on a particular day. This is a cross-sectional distribution. The other distribution is of the variation in daily ranges of individual cars over a period of time such as a year. This longitudinal distribution is of interest because it will indicate how often (if at all) and by how much the use of the individual vehicle exceeds its range.

Further work is required on the cross-sectional distributions of ranges since, as explained previously, the distributions derived for the

VRI study (Figures 2.2 to 2.7) were extremely crude. A possible source of data for cars is the National Travel Survey which has been conducted by the Department of Transport every third year since 1972/3. The survey covers many aspects of household travel including the use of household cars. The results of the survey are held in a computer data base from which it is possible to extract tabulations of any desired variable. For goods vehicles a possible source is the Continuing Survey of Road Goods Transport conducted by the Department of Transport. Its results are also held in a computer data base from which tabulations can be extracted.

Deriving longitudinal distributions for individual vehicles is likely to be more problematical because surveys such as the National Travel Survey and the Continuing Survey of Road Goods Vehicles are conducted over the year but individual returns are only for one week. Consequently the details known about any one vehicle are only for a week. As variations in daily ranges are likely to occur over a longer period than this, these surveys will be of limited use. However the National Travel Survey does record estimates of each cars annual mileage and whether it is a "first" car or a "second" car. Cross tabulations of maximum daily range in a week against average range in the week and annual mileage for individual months and "first" and "second" cars may be helpful in constructing synthetic longitudinal distributions. Other surveys of passenger travel, such as that conducted by British Rail of long distance journeys made by Manchester residents in 1974 (Beale and Paulley 1979), may also help.

Developments to Computer Models

In the analysis two computer models were used. These were the driving cycle model used to determine electric vehicle energy consumption and ranges and the electricity system used to determine possible modes of operation of the electricity system, its load factor and required installed capacities.

There are two areas in which further work could be done on driving cycle models. The first is the further development of the model used. There are several ways in which the model could be improved. One of which is the introduction of a method to take account of the variation in battery discharge efficiency with power output. At present the model uses a set of efficiencies which remain constant over the whole driving cycle. Another possible area for development is to incorporate the operation of internal combustion engined vehicles. This would require the development of a model of the drive system (including the gear ratios and its rotational inertia) and the engine's performance/efficiency over its range of operation (power output and engine speed).

The second area in which work could be done on driving cycle models is in the modelling of the complete driver: vehicle: road system: traffic set of interactions. Work done by Nowottny and Hardman (1977) and further reported by Waters and Laker (1980) has modelled the driver: vehicle: road system set of interactions and was calibrated using the results of instrumenting vehicles to analyse their energy consumption (Easingwood-Wilson, Nowottny and Pearce 1977). Such models could be very useful in design studies of vehicle energy use.

There are several areas in which further work on the electricity system model could be of benefit. These fall into three broad areas. These are refinement of the existing model, the introduction of more detail on road transport demands and the incorporation of intermittent sources of supply such as wave and wind power.

One of the short comings of the electricity system model is the use of a sinusoidal variation in average daily load over the year. Although the sinusoidal function used to model seasonal variations in demand may well be a reasonable reflection of the average load over a period of a month or so, it does not take account of the variation which occurs about this mean. There are two ways in which this could be overcome. One would be to introduce a random perturbation upon the sinusoidal function and the other would be to relate the variation in demand to weather variables such as temperature and sunshine. The latter approach is the more promising, particularly if combined with the other developments mentioned below. It is this approach which is being taken by Barrett (1981).

There are several ways in which the detail about road transport used in the model could be improved. These include the incorporation of daily traffic flows. The reports on the 50-point traffic census (Tanner and Scott 1962, Dunn 1962,3,4,5,6,7, Dunn and Sheppard 1968, Dunn 1970,1,2,3,4) give estimates of total vehicle miles on all classified roads in Great Britain for the years 1961 to 1972. These could be combined with the results of the monthly road side surveys reported in Highway Statistics (Department of the Environment annual) to obtain estimates of vehicle kilometers by cars, vans, rigid goods, articulated goods and buses. These results could be reduced to a common basis so that they could be used in projections in which the total annual mileages were different, and could then be used in place of the Fourier patterns used in the VRI study.

A second set of details which could be included are those on when vehicles are not in use during the day. These could be estimated from studies on vehicle flow rates, such as Gyenes (1973). The incorporation of such details would require modification to the model's consideration of "logic loads" so that it did not use more load than was connected at any one time.

Finally it would be advantageous to incorporate variable sources of supply, such as wind and wave power, into the model. An early attempt to do this for wave power (Vimukta, Baker and Plumpton 1978) had the short coming that it used randomly generated hourly data to represent wave power availability. Although the distribution of hourly outputs corresponded to that over a time period of several years there was no attempt made to model the auto correlation of the power available. This was due to lack of basic data. Until recently it has not been possible to use this approach to investigate wavepower and storage in anything but a speculative fashion as done by Chapman (1977). However a recent paper by Winter (1980) indicates that the Meteorological Office have developed a wave forecasting model which could be used to obtain time series estimates of wave spectra at 30 minute intervals for a large number of offshore sites. There is also better data available on wind power and Low is currently developing the model to incorporate-weather-record based estimates of Windpower availability (Low 1981).

Scenarios

There are two ways in which the scenarios used in the VRI study could be developed. The first would be to make simple alterations to the two existing scenarios to generate modified scenarios. Such modifications might involve taking the electric vehicle scenario and have all goods vehicles run on liquid fuels and have a separate operator run battery exchange system for buses so that public battery exchange would only be used for cars and vans. Another modification would be similar to this but would involve the use of mobile generators for use on long journeys instead of battery exchange.

The second way in which the scenarios used could be developed would be to use more extensive and sophisticated scenarios of energy use in the remainder of the economy such as those in A Low Energy Strategy for the United Kingdom (Leach, Lewis, Romig, van Buren and Foley 1979) and Energy Technologies for the United Kingdom (Department of Energy 1979). The use of such scenarios would also enable the dynamics of introducing synthetic liquid fuels from coal and of electric vehicles over time between now and 2025 to be examined.

Practical

Finally two areas which were identified in the VRI study and which require research, and possibly then development, are a cheap and simple 40 amp plug and socket, and a solid state recharger. One of the things which would be advantageous in such a recharger would be a variable charging voltage so that the current delivered could be kept constant for a large part of the charging cycle unlike the simple charger design envisaged in the VRI study.

2.6 Lessons I learnt from the VRI study

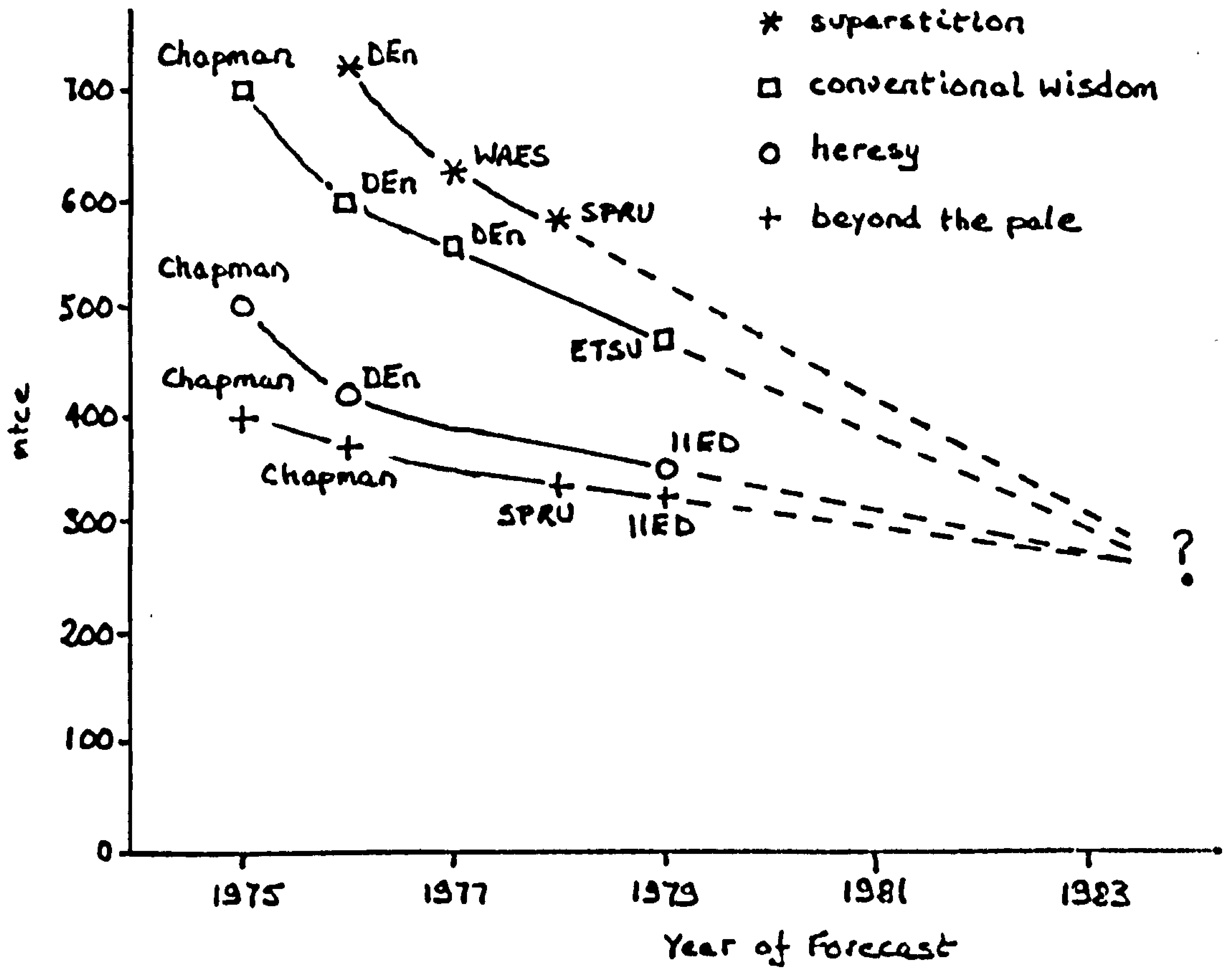
As with the Freight Transport Statistics study I learnt several valuable lessons from the refuelling infrastructure study.

Conformity

As with the FTF study there were several ways in which the VRI study was constrained to conform with the work and views of others. This ranged from technical issues such as electric vehicle energy consumption where modifications were made to the electric vehicle model until the results it produced were within a believable range. This believable range was set by the work of others in the field and their expectations. At the other end of the scale the GDP, energy and transport projections which were used were chosen on the basis that they would not prejudice the results of the study rather than on the basis that we thought they were particularly likely.

Support for the energy demand projections used in the FTF study was taken from them being broadly in line with those of the Department of Energy. It was the FTF demand projections which were used in the VRI study. However by the time it was conducted in 1978 and subsequently revised in 1980 general expectations of energy demand had fallen considerably, as can be seen from Figure 2.17.

In both the FTF and VRI studies Department of the Environment forecasts of traffic were used, not because they were thought to be particularly good, that is what is likely to happen, but because their use would not prejudice the studies results in the eyes of government.



After: Lovins (1979)

Figure 2.17 Forecasts of Primary Energy Demand in 2000

Cooking the books

In the process of revising the VRI study several small changes were made in the starting assumptions and projections. For example the recalculation of the vehicle energy consumptions and the "exchange" ranges led to an increase from 200 km range to 280 km range for cars. In its turn this led to a reduction from 1 million to 260 thousand for the number of exchanges required on an August Saturdy. This is an example of the effects of changing highly sensitive variables in an analysis. Although it was not done in this case such changes can often be made without seriously affecting the plausibility of the starting assumptions but radically change the end result. It is often very easy to cook the books.

Changes in behaviour

In the VRI study one of the difficulties for which no adequate solution could be found was that of new technologies changing patterns of behaviour. This came to light when considering the introduction of electric vehicles. The original intention was to make a comparison between scenarios in which the vehicles performed the same journey patterns. However it was found that the costs of journeys would, on a per kilometre basis, be much higher for long journeys than for short journeys. This would be likely to have the effect of changing behaviour patterns so as to reduce the number of long journeys made. No way of modelling such changes in behaviour were immediatley apparent and even if they had been their use would have rendered the two scenarios incompatible.

Reasonableness of constraints

There were other ways in which the construction of comparable scenarios led to problems. For example in the liquid fuelled vehicle scenario the limit on coal production of 258 million tonnes of coal seems much less reasonable than in the electric vehicle scenario. This is because in the liquid fuelled case there would be much greater pressures to increase coal production than in the electric case.

Data

Yet again there were problems with the data upon which models were constructed. For example the data on vehicle ranges is very sparse to the extent that the analysis caried out was more wishful thinking than anything else. Another example was the lack of data on seasonal variations in electricity demand for the electricity demand model.

Summary of lessons learnt

From these lessons I learnt that forecasting studies and scenario construction is often tailored to be acceptable to its audience. This entails keeping within the general bounds of current expectations. I also confirmed my belief that it would be possible to produce any desired result by the judicious choice of starting assumptions. Another thing I found out was that changes in behaviour can be ignored, but that if they are, the results will be that much less believable or useful. Another thing was that "comparable" scenarios are not necessarily very useful because the constraints of comparability can impose unrealistic constraints. Finally I again found that data can cause serious problems.

3. TRANSPORT INPUT-OUTPUT STUDY

3.1 Introduction

As I explained in Chapter 1, for the further work I intended to do on freight transport, I was going to use input-output tables to determine the net physical output of different commodities. This interest in freight transport and the use of input-output tables led to a third area of work. This was collecting data on the production and consumption of transport, and resource use by transport, in an input-output framework. The work I did was supported by the Transport and Road Research Laboratory and was principally of use to the Central Statistical Office in their construction of the 1974 input-output tables.

I thought that working on the 1974 tables would help me gain access to them. I also saw possibilities of relating freight transport demand to the physical output of, and inputs to, individual industries and hoped that working on the 1974 input-output tables might also help towards this.

3.2 Aims of the Transport Input-Output Study

The aim of the Transport Input-Output (TIO) study was to provide data on resource flows associated with the transport sector of the UK economy compatible with the input-output tables compiled by the Central Statistical Office. Several input-output tables have been constructed for the UK. Those for 1954, 1963, 1968 and 1974 (Central Statistical Office 1961, 1970, 1973, 1981) were based on detailed censuses of production. However the censuses of production do not cover the transport industries, which was the main reason why the TIO study was necessary. The principal objective was to prepare entries for the 1974 input-output tables. This work took so long that other objectives of extending the work to other years, such as 1968, and examining the linearity of the relationship between inputs and outputs was not possible.

The results of the TIO study reported in Baker (1979a, 1979b, and 1980) cover the financial, and some physical, inputs to, and outputs of, the transport industries. They also cover the road transport output of, and transport consumed by, other industries. The main sources I used were published statistics, including the reports and accounts of nationalized undertakings. I also used some unpublished statistics.

In this chapter I briefly describe how I obtained my results and then describe lessons I learnt about the reliability (or otherwise) of officially collected and compiled statistics.

3.3 Input-Output Tables

To facilitate my description of the work I did I shall first describe input-output tables, and the main sources used in their compilation.

> "Input-output tables are a means of showing the inter-relationships between the producers and consumers in the economy during a particular year. The principal difference between these tables and the more familiar analyses presented in the National Accounts is that the input-output tables show the flows between industries as buyers of each others' outputs in addition to the 'final' expenditure (by consumers, government, investors and on exports) and income identified in the National Accounts. In input-output terms the economy is considered as a system of industries linked together by flows of goods and services . . .
>
> Input-output tables were originally developed by Leontief (1951) for the American economy in the 1930's. The use of the inter-industry information meant that a much more complete picture of the economy could be built up with consequently improved possibilities for economic forecasting. In particular this method allows the implications of a change in demand for a particular commodity to be calculated for each industry in the economy rather than simply as an aggregate for the economy as a whole. In addition the input-output table is a system within which all the national accounts aggregates can be contained. Moreover, because it demands that inputs equal outputs for each industry it is a framework within which analysis of discrepancies between expenditure and income measures of the gross domestic product can be investigated in detail" (Johnson 1976).

Output, Input and Import Tables

There are three basic tables. These are the Output, Input and Import Tables. The first shows the output of commodities by each industry. The second shows the consumption of domestically produced commodities by each industry and final demand. Finally the third shows the consumption of imported commodities by each industry and final demand. The input table also shows imports of goods and services, net taxes on expenditure, and value added for each industry so that the total inputs equal the total outputs for each industry. Since the input table also shows the purchases of commodities by consumption, investment and exports (which make up final demand) the total production of a commodity from the output table is equal to the total consumption of each commodity in the input table. The import table is an expansion of the imports vector in the input table.

Industries and Commodities

The classification of industries used in the 1974 input-output tables is based upon the Standard Industrial Classification 1968 (SIC, Central Statistical Office 1975). The industries are defined in terms of one or more Minimum List Headings (MLH) from the SIC. Commodities are defined as the principal product of an industry. Consequently the output of service industries, including the transport industries are considered to be commodities.

Establishment

The major source of data from which the input-output tables are constructed is the Census of Production and Purchases Inquiry (CoP and PI, Business Statistics Office 1978 and 1979). The reports of the CoP and PI cover all manufactureing industries. That is MLH's 101 to 603. The CoP does not cover Agriculture, Forestry and fishing, nor does it cover Transport, Distribution, nor other private and public services. The basic reporting unit for the CoP and PI is the establishment. Establishments are classified by their principal product and not by their ownership. For example the rail workshops of British Rail Engineering Ltd. are classified as MLHs 384 or 385, Locomotive and Railway Track Equipment or Railway

Carriages and Wagons and Trams not as MLH 701 Railways. Since the major source of data for the input-output tables is based upon the establishment, so are the tables themselves.

Imports

From the PI can be built up a table of the consumption of commodities by each industry. However the PI does not distinguish between domestically produced and imported commodities. Consequently to obtain the input table, imports must be subtracted from the table of consumption. The basic source of data on imports is the Trade of the United Kingdom (Her Majesty's Customs and Excise annual). This lists in very great detail the imports and exports of goods. Each commodity listed as an import is assigned to an industry or final demand which is assumed to import it.

3.4 Transport entries for the 1974 Input-Output Table

As mentioned above the grouping into industry/commodity groups which I used was that used in the 1974 input-output tables. It was based upon single or groups of Minimum List Headings from the Standard Industrial Classification 1968 (Central Statistical Office 1975). An extract from the SIC, of Order XXII - Transport and Communication, rearranged into the input-output groupings is given in Table 3.1.

Table 3.1 SIC Order XXII – Transport and Communication

I.O. No	Minimum List Heading	
93	701	**Railways** Railways including both the underground and surface railways operated by the London Transport Board. Ancillary undertakings, such as locomotive, carriage and wagon workshops, catering services, air, omnibus or steamer services, docks and canals, are classified in their appropriate headings.
94	702	**Road Passenger Transport** **1. Omnibus and tramway service** The operation of omnibus, motor coach, trolleybus and tramway services. **2. Taxis and private-hire cars** The operation of taxi-cabs and private-hire cars; owner-drivers are included. Car hire is also included.
	703	**Road Haulage Contracting for General Hire or Reward** Cartage and haulage contractors (whether using motor or horse-drawn vehicles) of all types, including furniture removers, mainly operating for general hire or reward. Hire of commercial vehicles is included. Establishments mainly carrying goods in connection with another business operated under common ownership or control are classified in Heading 704.
	704	**Other Road Haulage** Cartage and haulage undertakings (whether using motor or horse-drawn vehicles) of all types mainly engaged in carrying goods in connection with another business operated under common ownership or control.
95	705	**Sea Transport** **1. Shipping company (shore establishments)** The shore establishments of companies (including railways) operating sea-going ships for the conveyance of either passengers or cargo. The operation of fishing vessels is classified in Heading 003. **2. Shipping company (sea-going personnel)** The crews of sea-going merchant ships, other than fishing vessels. **3. Pilotage** The provision of pilots for sea-going ships.
	706	**Port and Inland Water Transport** Harbour, dock, canal, lighthouse, lightship, etc. authorities, and establishments conducting marine salvage operations; the loading and unloading of vessels and the operation of tugs, lighters, barges, ferries, etc., in ports and inland waterways. The hiring of pleasure boats, punts, etc., is classified in Heading 882.
96	707	**Air Transport** Air line companies operating on regular schedules or on charter (including establishments of Commonwealth and foreign air lines in the United Kingdom), and aerodromes, including airports, air traffic control centres, and communication centres operated by the Board of Trade. Flying schools and flying and glider clubs are classified in Headings 709 and 882 respectively.
	709	**Miscellaneous Transport Services and Storage** **1. Services incidental to transport** Ship brokers, freight brokers, shipping agents, forwarding agents, travel ticket agents, tourist and excursion agents and similar establishments which facilitate the transport of passengers or goods but are not transport operators; flying schools, motoring schools, car parks, the road patrols and other motoring services of the motorists' organisations; the operation of toll roads and toll bridges. **2. Storage** Warehouses (including bonded warehouses), cold storage, furniture repositories, safe deposits, etc. **3. Other** Providing messenger service or porterage; hiring hand trucks, barrows, tradesmen's cycles, bath-chairs, etc.
97	708	**Postal Services and Telecommunications** All Post Office establishments, except the factories manufacturing and repairing telephone and telegraph apparatus (classified in Heading 363) and the Post Office Savings Department and Post Office Giro (classified in Heading 861); cable and radio services (excluding broadcasting and radio relay services) and other telephone or telegraph services.

Figures 3.1 and 3.2 show the numbers I was attempting to obtain in the TIO study.

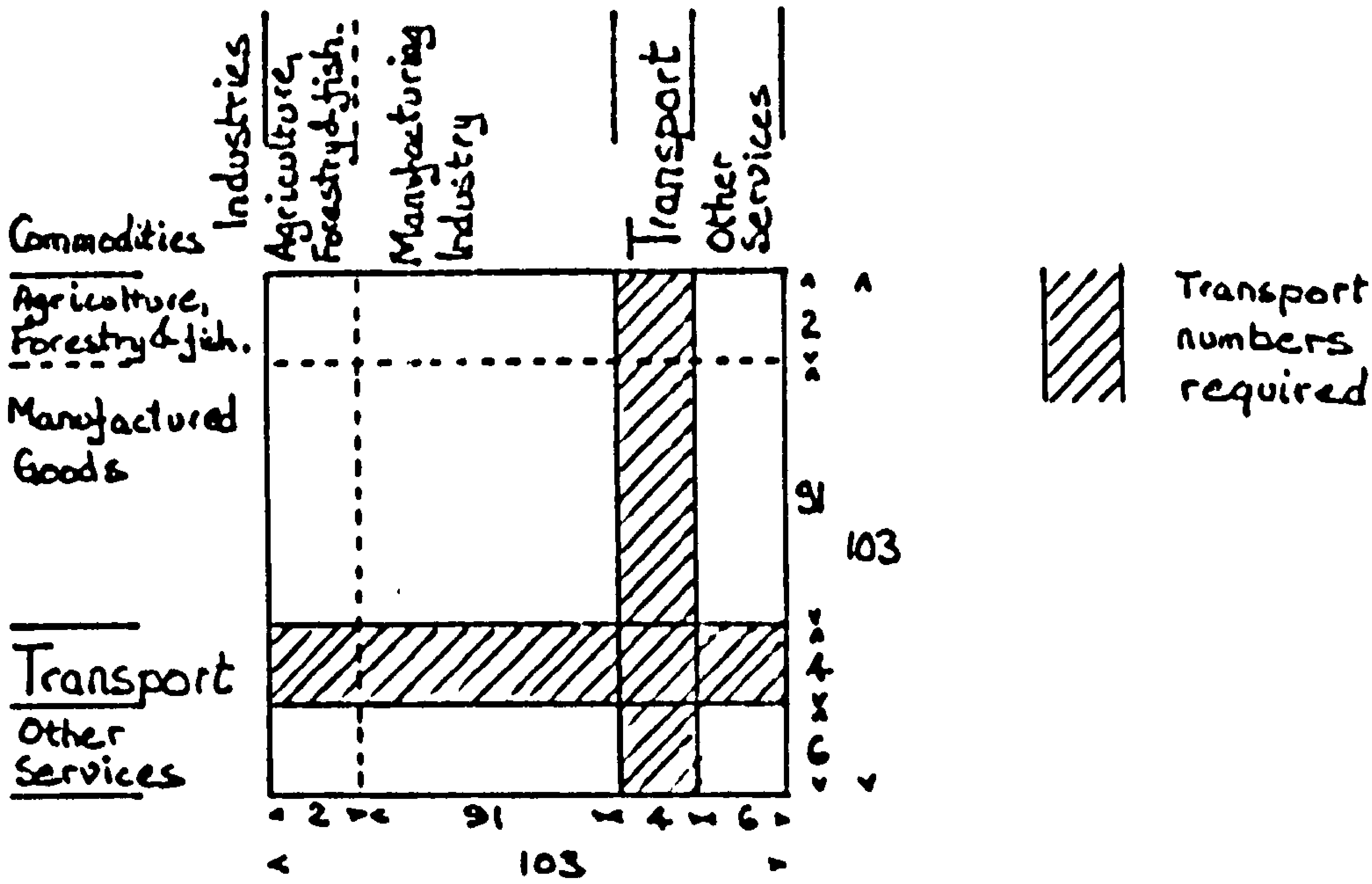


Figure 3.1 Numbers required for the Output Table

On the output side I was attempting to obtain figures on the output of all commodities by the Transport industries. In total this was 412 numbers (4 industries by 103 commodities). However the transport industries have very few outputs other than transport so that most of these 412 numbers were zero. I was also trying to find the output of transport by non transport industries. This was 396 numbers (4 commodities by 99 industries).

Due to difficulties in obtaining data I assumed that the only transport which was produced by non transport industries was road haulage. That is I assumed all rail, ship, air and road passenger transport was only produced by the respective industries. This meant that I assumed that 297 of the required numbers were zero.

On the input side I was concerned with the inputs of commodities and value added (108) to the transport industries (4) which meant I was looking for 424 numbers and also with the inputs of transport (4) to non-transport industries (99) which led to looking for 396 numbers.

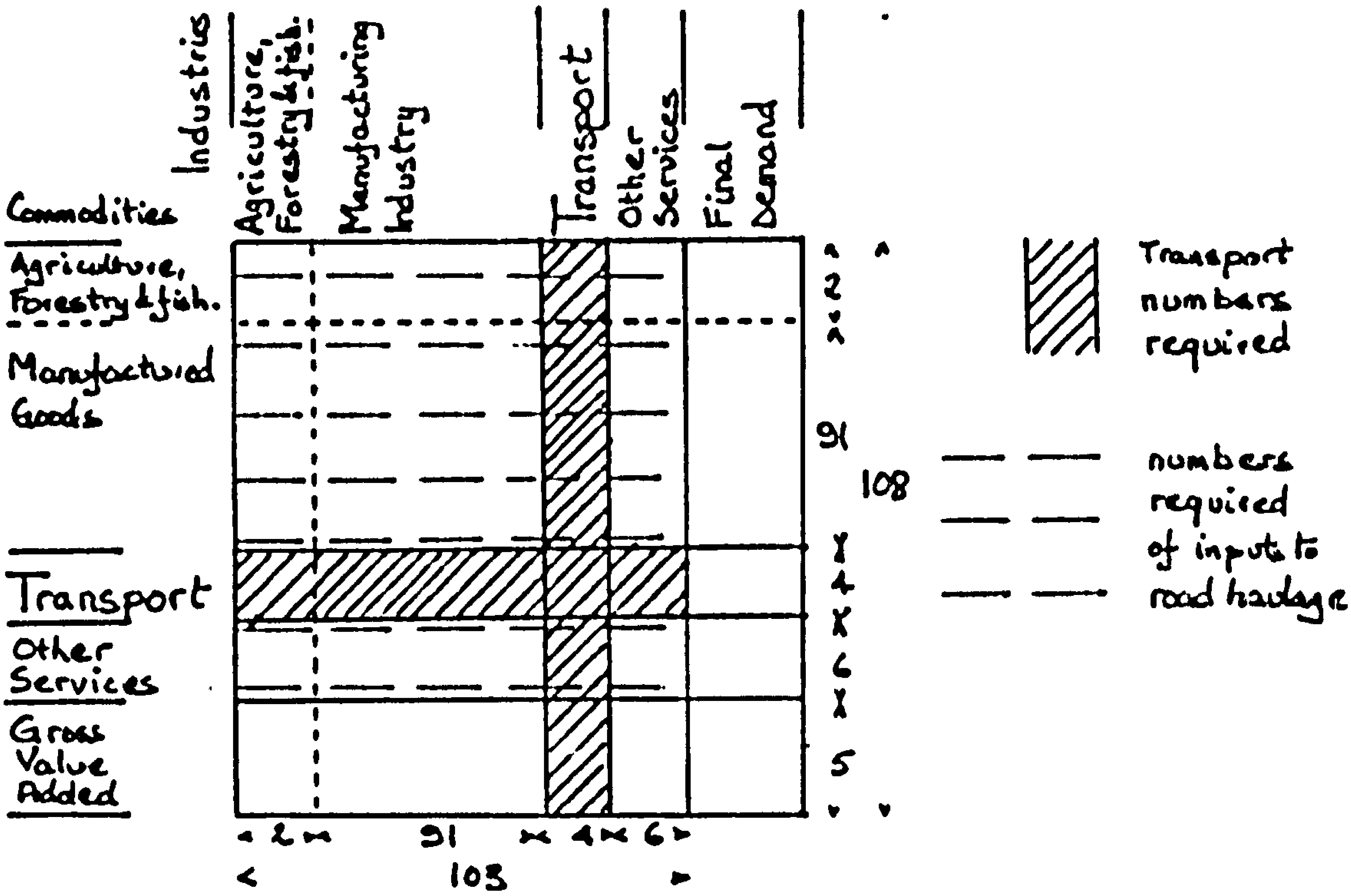


Figure 3.2 Numbers required for the Input and Import Tables

To determine the output of road haulage by all industries I estimated the total of all inputs to industries for the provision of road haulage. Potentially this could have required 11124 numbers (108 commodities and value added by 103 industries).

Apart from the output of the Transport industries I was unable to obtain all of the numbers required. For all but the input of Transport to industries I was able to find the total inputs or outputs but was not able to get a complete breakdown into the required categories. For example I was only able to obtain one number representing the output of road haulage by Agriculture, Forestry and Fishing, where as I required two, one for Agriculture and one for Forestry and Fishing.

The extent to which I was able to obtain all of the required numbers is illustrated in Figures 3.3 to 3.7.
These show the proportion of the totals of input or output respectively (on the vertical axis) which were at the required level of disagregation and by how much the others fell short of this (coverage factor, on the

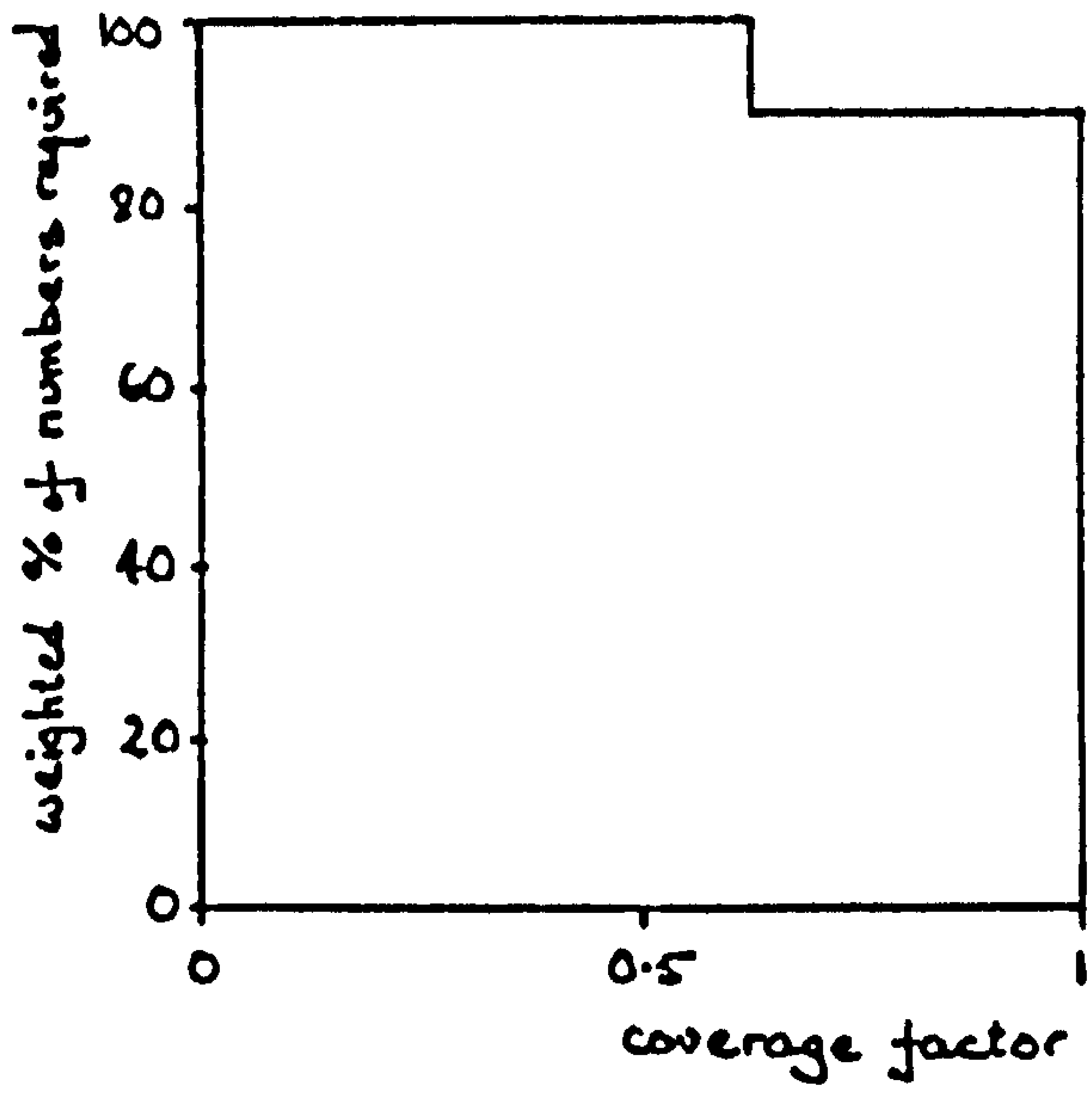


Figure 3.3 Extent to which numbers were found - Output of Transport (by non transport industries)

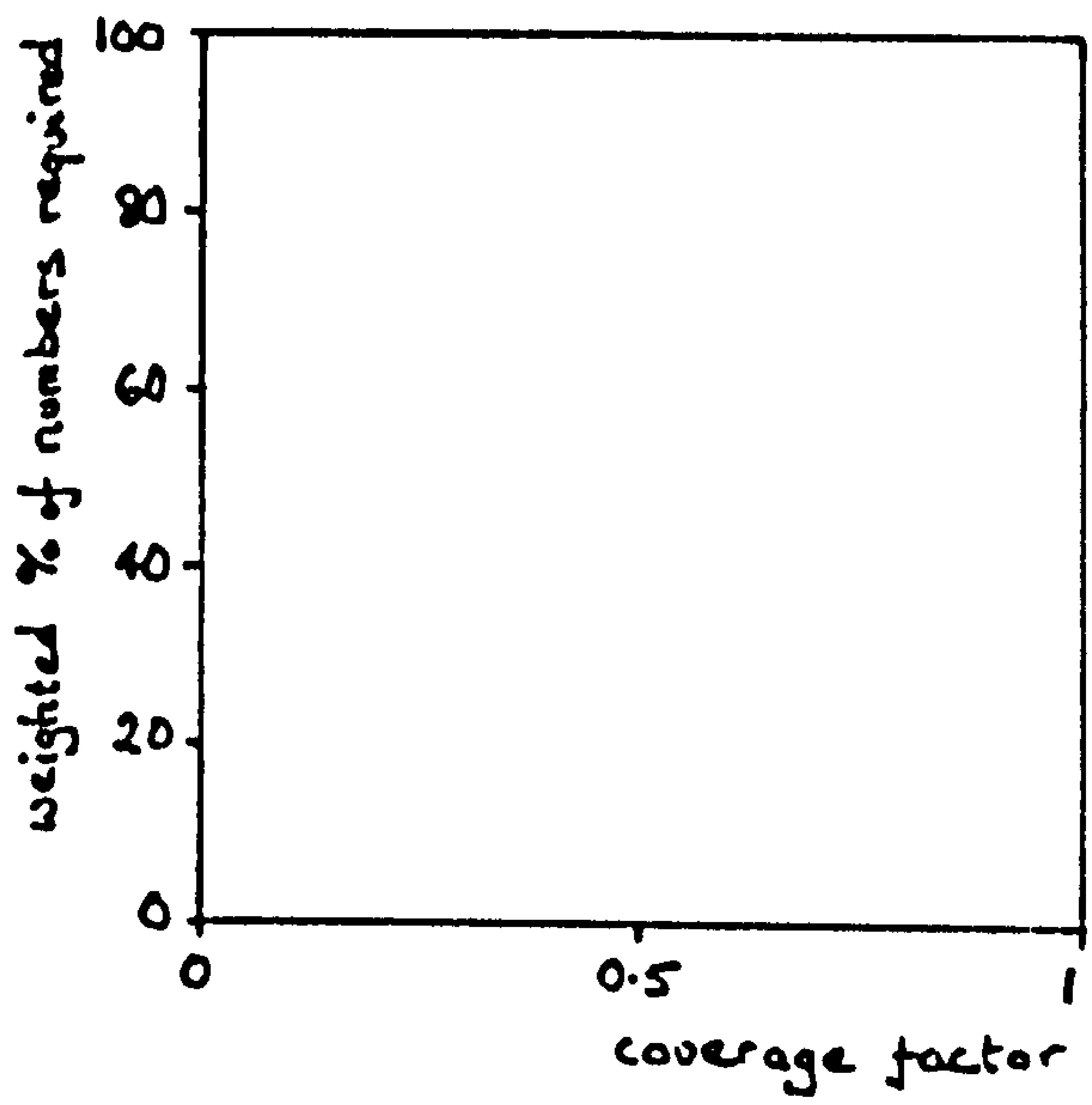


Figure 3.4 Extent to which numbers were found - Output by Transport Industries

horizontal axis). The coverage factor is the ratio of numbers found to numbers required.

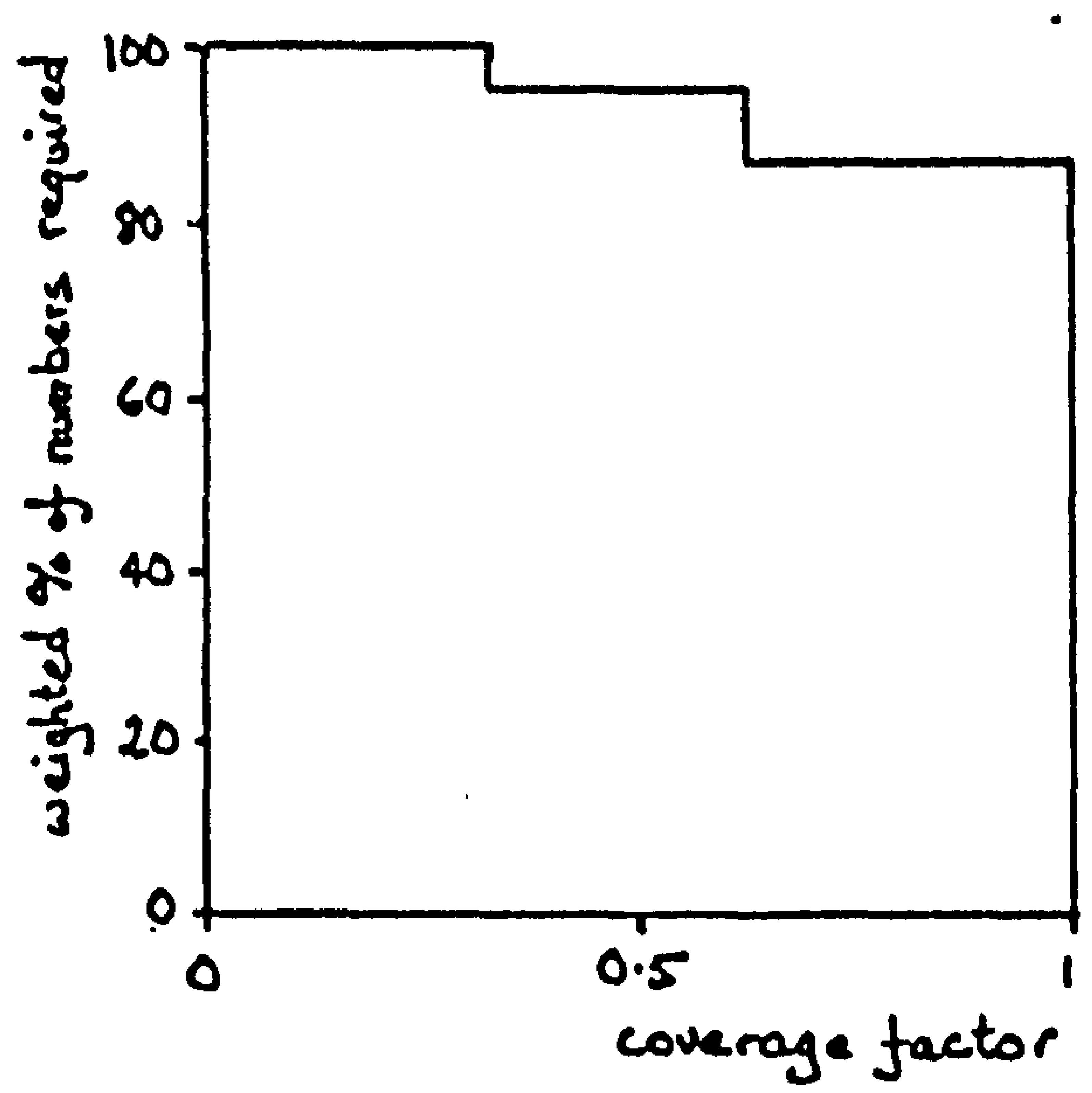


Figure 3.5 Extent to which numbers were found - Input of Transport to Industires

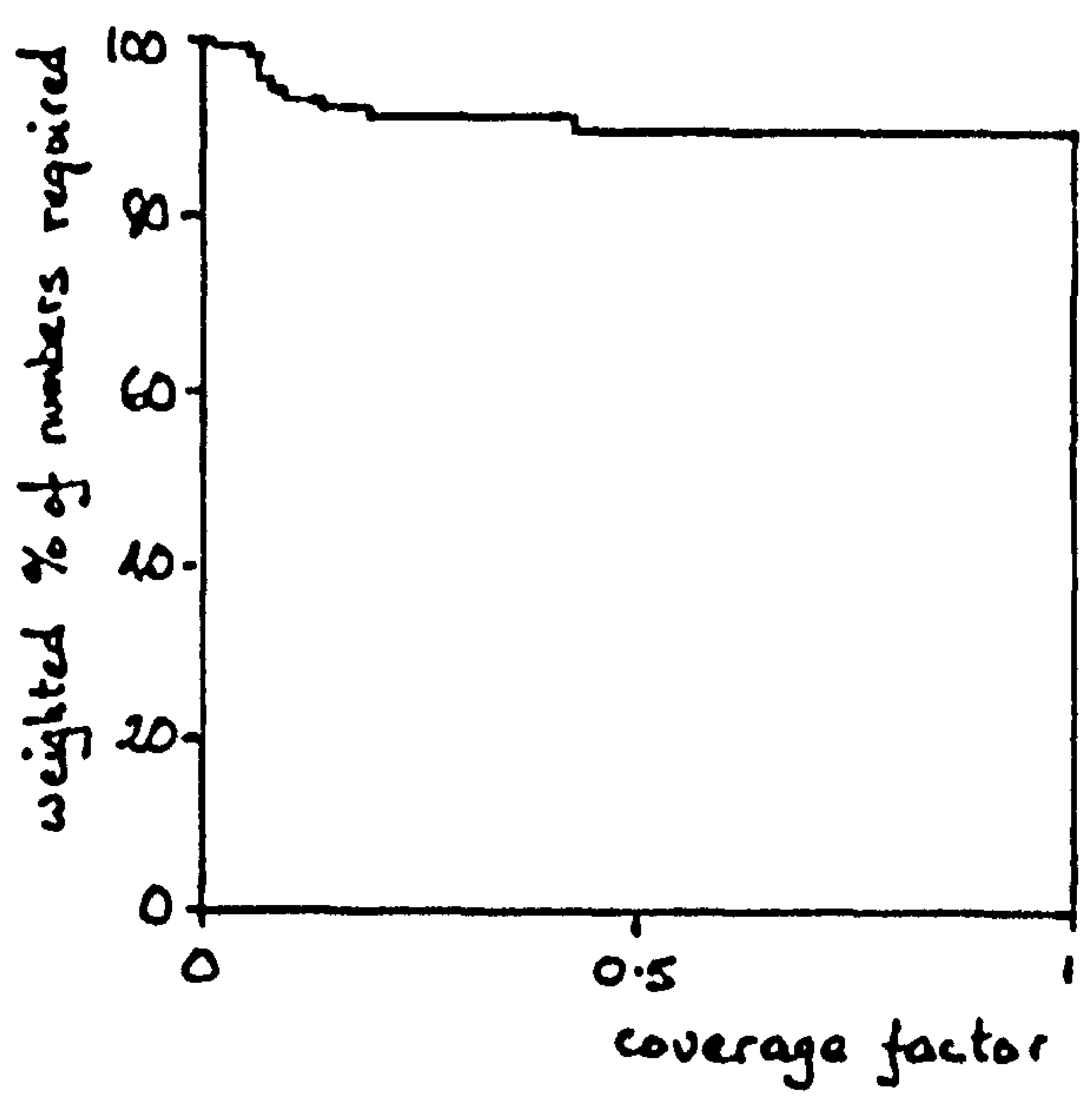


Figure 3.6 Extent to which numbers were found - Input to Transport Industries

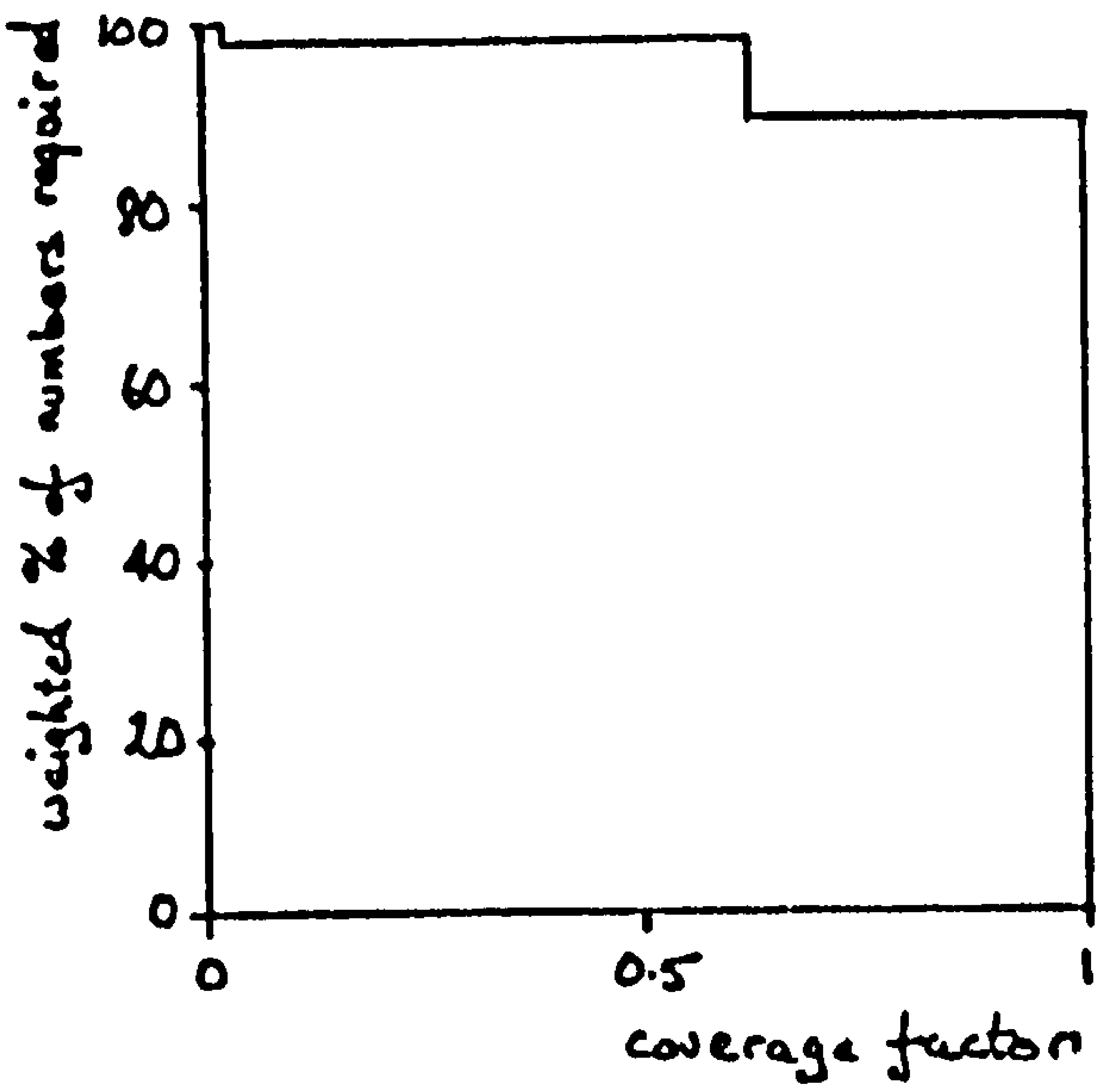


Figure 3.7 Extent to which numbers were found - Input to the Road Haulage produced by all industries

3.5 Lessons I learnt from the Transport Input-Output Study

Having become a "World expert on UK transport statistics" (Johnson 1979, see Appendix 5) and been congratulated "on the thoroughness and care that have obviously been taken to arrive at . . . very comprehensive results [in the TIO study]" (Lockeyer 1979, see Appendix 5). I still have many reservations about the reliability of the work I did.

There were two basic lessons which I learnt from the TIO study. These were that statistics are often unreliable and that very little attention is paid to assessing or specifying their reliability. In the following sections I give examples of why statistics are unreliable and why I have concluded that too little attention is paid to reliability.

Why statistics are unreliable

From my work on the TIO study I can identify five ways in which the way that Statistics are compiled leads to their being unreliable. These can be summarised as secrecy, estimation of incomplete data, the tortuous recombination of data, dubious sources of data, and incomplete enumeration.

Secrecy

In the TIO study some of the data I obtained was released to me on the basis that I did not reveal its source. For some other data I was able to quote the source but was unable to quote the data without manipulating it sufficiently so that the original data could not be inferred from my report.

In the first case where I was unable to quote the source of my data I had to resort to saying that "CSO have provided . . . estimates" (Baker 1979a). The Input-Output section of CSO for whom the TIO study was conducted know what the source is and how reliable they think this source is. However any one else who reads my report (Baker 1979a) will be unable to either reproduce my work or to judge how relibale these "estimates" might be.

In the other cases of secrecy I was able to quote my sources. However, because of the apparently sensitive nature of the data which had been collected (General Council of British Shipping 1977), and the rules governing confidentiality (Department of Transport 1979a), I was unable to quote the basic data from which I worked. Again in these two cases any one reading my report who does not have access to either of these two sources will be unable to check for themselves whether the work I did was reasonable or accurate.

It is one of the basic assumptions underlying the operation of a free market (upon which economic theory is based) that everyone has access to perfect information. However these examples show some of the ways in which secrecy prevents free access to information which would be a necessary prerequisite for perfect information.

Estimation of incomplete data

There are very few sources of data [1] which are based upon complete

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[1] That is data of the sort which is used in making long term forecasts (such as economic, transport and energy) for policy purposes.

surveys. One of these is the Population Census. Most sources of data do not cover the whole of the population being surveyed and some way is used to make whole population estimates.

In the TIO study I came across several cases in which either I or others had had to make such estimates. I shall describe those necessary for data from the Census of Production, the Continuing Survey of Road Goods Transport and the National Travel Survey.

The data which I used from the Census of Production (Business Statistics Office 1978 & 1979) was only collected for larger establishments (that is employing 50 or more people). To obtain estimates of expenditure by all establishments I had to multiply the larger establishments' expenditures by the ratio of total expenditure by all establishments, to that by larger establishments. This would only give a correct result if the patterns of expenditure in larger and smaller establaishments were the same. However I think that is is quite certain that they are not, but there is no way of knowing because a detailed breakdown of smaller establishments expenditures is not available.

The Continuing Survey of Road Goods Transport (CSRGT Department of Transport 1979a) is a sample survey. Of the 560.1 thousand goods vehicles over 3.5 tonnes Gross Vehicle Weight (GVW) in 1974 (Department of Transport annual a) 17640 were surveyed. The operator of each vehicle was required to provide details of the work performed by the vehicle during one week. Approximately equal numbers of vehicles were sampled in each week of the year. The grossing factors for numbers of vehicles were approximately 30 and those for vehicle km were approximately 1500.

I used data from both the 1972/3 and the 1975/6 National Travel Surveys (NTS, Department of Transport 1979b). These were both sample surveys in which households were asked to give details of all journeys made by the members of the households during one week. As with the CSRGT the weeks were spread through out the year of the survey. The 1972/3 NTS covered a population of 16836 out of a UK population of 51.786 million and that for 1975/6 covered 27906 out of 52.306 million. This led me to use grossing factors of 160387 and 91735 respectively for data from the two NTSs.

Tortuous Recombination of Data

I shall illustrate the necessity of having to resort to tortuous recombination of data by describing what I had to do to make estimates of the financial inputs to, and output of, road haulage.

What I wanted were the expenditures made by each of the 102 input-output industries in their operation of road haulage. I also wanted these expenditures to be broken down by the 102 input-output commodities and split between the provision of own account and public haulage operations. From the total of all expenditures (including profits) I would be able to estimate the output of road haulage by each industry.

The data which I used and its sources is shown in Table 3.2.

Table 3.2 Data sources on Road Haulage

Source	Data on	Coverage	Data from
ACoP/PI	fuel, tyres + spares, repairs + maintenance, licences	Manufacturing Industry by MLH	survey of all larger establishments
Various	as for ACoP/PI	Distribution	as for ACOP/PI
CM	unit costs /km: fuel, lubricants, tyres, maintenance, depreciation /vehicle: insurance, licences, interest, rent + rates, wages	GVW	Unknown
CSRGT	number of vehicles and vehicle km	SIC order by own account & public haulage and by GVW	Sample survey grossed to national total
OCinRFT	fuel + lubricants, spares, tyres, other materials, hiring vehicles, insurance, licences, rates, HP interest, other overheads, wages, depreciation	own account & public haulage in 1965	sample survey grossed to national totals

None of this data covered all inputs to the road haulage operation of all industries. The Annual Census of Production and Purchases Inquiry

(ACoP/PI, Business Statistics Office 1978 & 1979) covered about three quarters of the cost of commodities purchased for road haulage operations by manufacturing industries. This was the only source of data which was sufficiently disaggregated to get details for individual IO industries. (I obtained similar data to that provided by ACoP/PI for Distribution from the surveys of Wholesaling and of Retail Distribution (Business Statistics Office 1979 and Business Statistics Office 1977).)

From the Continuing Survey of Road Goods Transport (CSRGT, Department of Transport 1979a) I was able to obtain estimates of the numbers of vehicles and vehicle km broken down by Gross Vehicle Weight (GVW) and SIC order. This was the only source of data which covered all road haulage.

From the Commercial Motor Tables of Operating Costs (CM, Commercial Motor 1975) I was able to obtain unit costs for the operation of road goods vehicles (per vehicle km and per vehicle) broken down by GVW. This was the only source of data which covered all of the inputs to the road haulage operation (that is the total of all these costs is equal to the output of road haulage).

To make comparisons between the categories of expenditure from ACoP/PI and CM and those I wanted (i.e. in IO commodities) I used Operating Costs in Road Freight Transport (OCinRFT, Edwards and Bayliss 1970). However the data in this was for 1965.

The above can be summarised by saying:

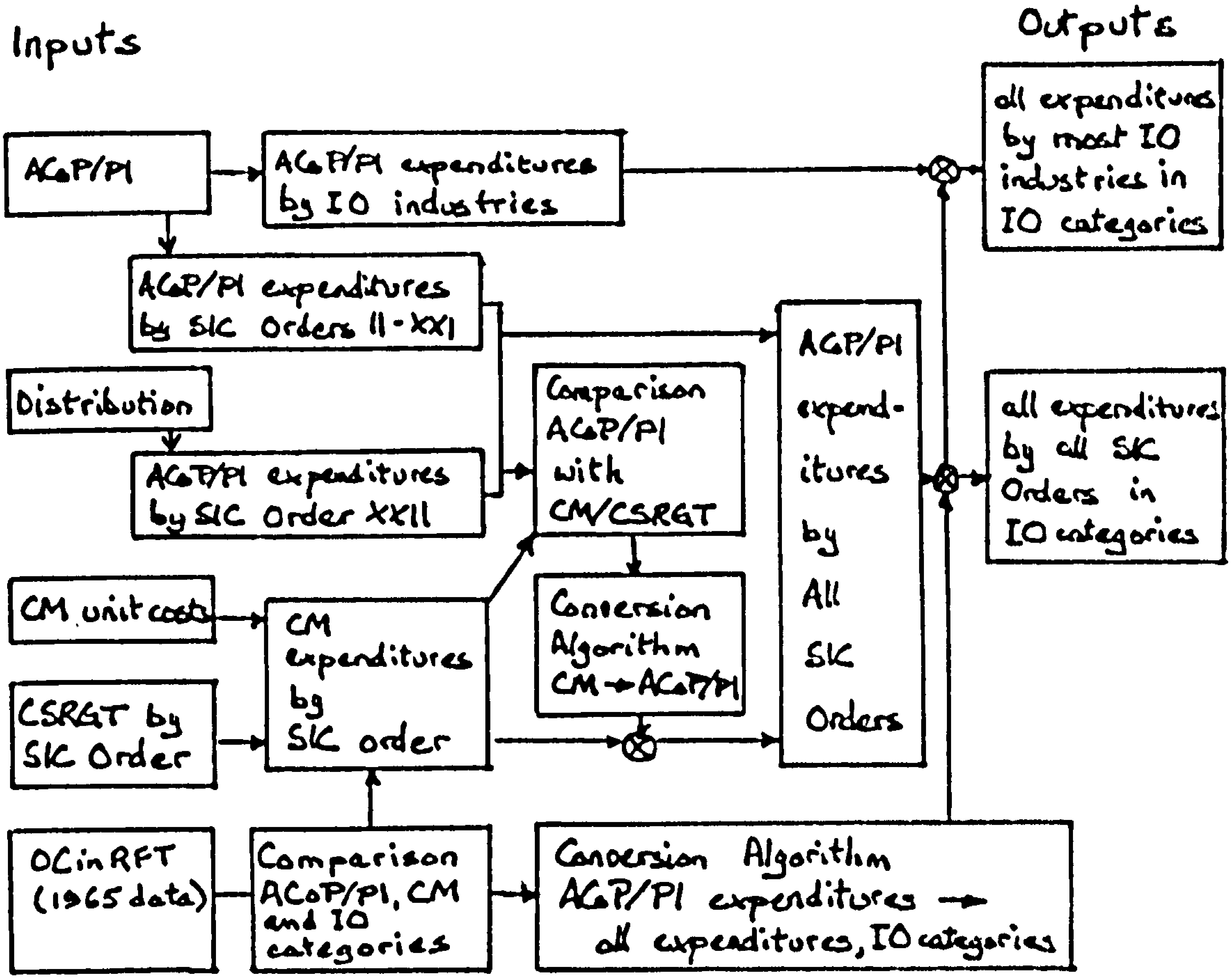
(a) only one source was sufficiently disagregated to get data at the industry level but it did not cover all industries or inputs;

(b) only one source covered all road haulage but it gave no data on inputs;

(c) only one source covered the unit costs of all inputs to road haulage but gave no data on total costs;

(d) the only source which could be used to compare the cost categories gave details of expenditures in 1965 rather than 1974.

The ways in which these sources were combined is illustrated in Figure 3.8.



ACoP/PI — Annual Census of Production and Purchases Inquiry (categories of expenditure)
SIC — Standard Industrial Classification
CM — Commercial Motor Tables of Operating Costs (categories of expenditure)
CSRGT — Continuing Survey of Road Goods Transport - physical output
IO — Input-Output
OCinRFT — Operating Costs in Road Freight Transport

Figure 3.8 How Data on Road Haulage was manipulated

Basicaly I did the following.

(a) I aggregated the ACoP/PI data to IO industry and SIC order levels.

(b) I obtained data on the same four categories of expenditure as that in ACoP/PI for Wholesale distribution from Business Statistics Office (1979) and for Retail distribution from Business Statistics Office

(1977). The data on Retail distribution was for 1971. I adjusted it for changes in the level of retail activity using data from the Annual Abstract of Statistics (Central Statistical Office annual a). I also adjusted for inflation by using data from Commercial Motor (1971 and 1975) [2].

(c) I multiplied the CM unit costs by the numbers of vehicles and vehicle km from the CSRGT for each GVW group and summed these over all GVW groups to get estimates of all inputs to the road haulage operations of each SIC order. Having compared estimates of total expenditure with those in OCinRFT I decided to make rather arbitary reductions to the CM unit costs for rent and rates, interest and insurance.

(d) I compared the estimates of some of the expenditures in CM categories with those from ACoP/PI and Distribution. From this comparison I derived a conversion algorithm for making estimates of expenditures in the ACoP/PI categories for SIC orders not covered by ACoP/PI.

(e) I used data from OCinRFT to compare the categories of expenditure from ACoP/PI with those in CM and the IO commodities. From this comparison I derived an algorithm to make estimates of all expenditures on the basis of the four ACoP/PI expenditures. I used this conversion algorithm to derive estimates of all expenditures (in ten IO categories) for the majority of IO industries and also for all SIC orders.

This is just one example of the tortuous recombination of data out of many which I could have chosen from the TIO study. In fact I had to employ similar procedures for each of the transport industries. Such tortuous recombination of data is necessary when the data being used is from different sources. In such cases it is usual that the data was originally collected for different purposes, it has different coverages and uses different classifications.

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[2] Together Retail and Wholesale distribution form one SIC order which is also one IO industry.

In situations where the tortuous recombination of data is necessary it is often difficult to understand what was done..This is important because it then becomes very difficult to follow how the reliability of the input data effects the reliability of the output. Also, the more complex is the manipulation, the more chance is there for errors to be made. For example such errors include the misallocation of numbers to categories when converting from one classification system to another.

Use of dubious sources

In the TIO study I had to resort to several dubious sources. That is sources which I either considered to be unreliable and/or I knew nothing of the way their statistics were compiled and/or I did not think the data was representative. In each of the cases where I did use a dubious source it was because it was the only source of data I could find. One example of a dubious source is Commercial Motor (1975) from which I obtained unit operating costs for goods vehicles (see above) and for buses and taxis. In each issue of the Commercial Motor Tables of Operating Costs details are given on how the various costs have changed since the previous year. For example:

> "Following the average inflationary trend of 10 per cent, . . . , insurance premiums have been increased in the main by that amount as has the rent and rates factor." (Commercial Motor 1975)

No indication is given how the data used in the Tables is collected but it seems unlikely that it is simply inflated by some arbitary amount each year, as the above might suggest, since such a procedure would lead to very inaccurate costs after several years. Another example of a dubious source I used was data provided to me by CSO on the inputs to Agriculture. In this case I considered the data to be dubious because I was totaly unaware of how it had been compiled and I knew of no surveys upon.which it might have been based.

A third example of a dubious source was the use of a National Board for Prices and Incomes (NBPI, 1968) report on London taxi fares. I used it to make an estimate of the number of vehicle miles run by taxis per passenger mile. I did this so that I could convert estimates of passenger km, from the National Travel Survey (Department of Transport 1979b), to vehicle km.

However I would be very suprised if the operation of London taxis led to the same ratio of vehicle to passenger km as that for taxis and hire cars nationally.

When using dubious sources such as these I feel uncomfortable because I don't know how reliable they are, and often suspect that they are of poor reliability.

Incomplete enumeration

Another reliability problem I came across in the TIO study was that of enumeration. For each of the industries I covered I had to try and ensure that I collected data on the whole industry. To do this I first had to list or enumerate the components of the industry. However, short of having a list of all establishments in the UK and assigning each one to an industry, there is no way of knowing if a list of the components of an industry is complete.

As an example of incomplete enumeration I recently found that the list of 'other railways' in Department of Transport (annual a) that I used was incomplete. In this instance the omission will have had negligible effect on the reliability of the estimates for railways since 'other railways' are such a small component of the total. However this illustrates the fact that it is not possible to be certain that all components of an industry have been enumerated (without an inordinate amount of work, see above). In brief **I can not know what I do not know.**

In the TIO study I also came across a longstanding case of incomplete enumeration. For many years the Department of Transport (and its predecessors), in making tables of Freight Transport in GB by all modes (Department of Transport annual a, and Central Statistical Office annual a), have used British Waterways (BWB) figures for total waterway freight transport. They have done this without making any reference to any other inland waterway operations. Baldwin (1977) has estimated (on the basis of a survey) that only a small part of inland waterway freight is carried on BWB waterways.

Inadequate attention to specifying reliability

In the previous section I looked at some of the reasons why statistics are unreliable. In this section I shall look at the reasons why I and others have paid very little attention to specifying the reliability of statistics.

Probably the most important reason for not specifying the reliability of statistics is that there appears to be very little demand for estimates of reliability. For example when the TIO study was set up there was no request that estimates of reliability be made. The necessity for such estimates was only agreed upon later at one of the project progress meetings.

A second reason for little attention being paid to the reliability of statistical estimates is that it is generally acknowledged that to make rigorous or objective estimates of reliability is either very difficult or impossible. In this situation the best that can usually be done is for the person compiling the statistics to make subjective judgements of their reliability.

One of the few descriptions of the reliability of a set of official statistics is given in Maurice (1968). It was upon that description that I based my own classification of reliability in my report on the TIO study.

> "It will be clear from the review of the data used that it is impossible to calculate statistical margins of error of the kind that are derived from random samples for any of the aggregates or for most of their components. It is however possible, from knowledge of the data, to form very rough and subjective judgements of the range of reasonable doubt attaching to the estimates. This is done in the sections concerned with the detailed estimates. Wherever possible these judgments are standardised by the use of uniform gradings, as follows:
>
> | | Margin of error |
> |---|---|
> | A | ± less than 3 per cent |
> | B | ± 3 per cent to 10 per cent |
> | C | ± more than 10 per cent |
>
> The terms 'good', 'fair' and 'poor' are used at some points and are broadly equivalent to categories A, B and C. Like margins of error derived from random samples, these judgements do not represent absolute certainty. They may be taken to mean that, in the opinion of the author and in the present state of knowledge, there is, say, a 90

per cent chance that the true value of the figures referred to lies within the limits of the grading." (Baker 1979a)

The main reason why so little attention is paid to specifying reliability is the amount of work which would be required to make anything other than subjective assessments. For example in the TIO study to determine the reliability of the road freight transport estimates (as described above) it would be necessary to conduct at the least a sample survey of all road freight transport. Such a survey would take longer and more effort than my original estimates. It would also yield results which were more reliable than the original estimates. However it might be very hard to estimate how reliable, since to do so might need an even bigger survey.

One way of getting an idea of the reliability of estimates is to make the estimates by using two or more independent methods. For example in my work on Road Haulage (see above) I made an estimate of the gross profit of the road haulage industry. After making a preliminary estimate of the inputs to and output of road haulage I received a request from F Johnson of the CSO for advice on sources of data on road haulage. He was interested in the gross profit in the Road Haulage industry and commented that my estimate was about twice the revenue estimate (see correspondence in Appendix 5). In my reply I sent details of my second round estimates in which my estimate of gross profit was about half of the first estimate. Up to this point the two estimates were independent (in that different sources were used and no communication had taken place between those making the estimates). However before finishing the work on road haulage I made a third round set of estimates (as shown in Appendix 5). In this third round the estimate of gross profit (£m 434.8) was very similar to that in the second round (£m 448.6). However had the revenue estimate been very different from my second round estimate it is likely that this would have influenced my third round estimate. It is likely that the nearness of the second round and revenue estimates reduced my attention to the gross profit estimate in the third round. The point of all this is to say that by the third round my estimate of gross profit was not independent of the revenue estimate just because I knew of its existance.

Independent estimates can be used as a check on their own reliability. However it is very difficult to arrive at indipendent estimates.

Finally when making subjective judgements of reliability I am very aware that I am likely to overestimate their reliability rather than underestimate. This is because the higher the reliability the more worthwhile is the result, and so the more worthwhile was the work involved. I don't like doing worthless work. I suspect that I may well have over estimated the reliability of the results in the TIO study for this very reason, and I also suspect that others are prone to the same pitfall.

3.6 Conclusion

From the TIO study I learnt lessons, or reinforced earlier lessons, on the nature of statistics. These lessons are that data is difficult to obtain, the data which does exist is not necessarily freely available, that it is often unreliable, that different sources often give different answers for the same thing. Finally I found that gathering and collating statistics can be very monotonous.

4. REVIEW OF LESSONS LEARNT

In this very brief chapter I shall review the lessons I have learnt about forecasting.

4.1 More detail

By including more detail in the analysis of past data and in modelling of a system it is possible to gain a greater understanding of what has happened in the past. However this is usually at the expense of increased complexity when it comes to using such a model for making forecasts. The problem arises because each explanatory variable which is added to the model requires its own projection to make a forecast. Effectively this means that more detail in an analysis or model requires more forecasts if it is to be used for forecasting purposes.

4.2 Data problems

There are at least four major problems with data.

(a) It is possible to construct models of reality for which no data exists. An example of this is a multi-region input-output model for which the data is not available in the UK. The model can be built in theory but in practice it can not be calibrated. As well as data not being available, that which does exist is often incomplete as I found in the case of inland waterways (in the TIO study) and in gathering data on physical imports (in the freight transport study).

(b) Data is not reliable due to the way it is collected.

(c) Different sources of data on the same thing often give different estimates. For example in my work on the TIO study my estimates of output varied from those of another source used by the Central Statistical Office by a significant amount.

(d) Data is difficult to obtain. When data does exist it is not always possible to get access to it. There are many reasons for this. One of the many ones being the conditions under which the data was collected. For example surveys of business conducted by the government are done under rules of confidentiallity. One of these rules is that figures relating to less than 6 respondents may not be released. Another is that where a figure from one response represents 75% or more of a total, that total may not be released. These rules led to potential problems in the TIO study where the detail I required for my analysis required data below these confidentiality limits. It was only on giving an undertaking that the data would be aggregated before publication that I was given access to it.

In another instance in the TIO study I was given an unpublished report from which I could only quote total figures. In a draft report I included tables derived form this report to show how I had arrived at some figures, but I was asked to remove them.

In summary data is often incomplete, inaccurate, inconsistent and difficult to obtain.

4.3 Scenarios

Although the use of scenarios avoids some of the problems of using forecasts, such as being unable to say which of the possible sets of futures will be "the" future, scenarios have problems of their own. For example it is very easy for those using a scenario to mistake it for a forecast. It is also very easy to call a forecast a scenario but treat it as a forecast in all but name. I think that this is what happened with the ETSU scenario in Energy Paper 39 (Department of Energy 1979).

Another way in which problems can arrise in using scenarios is when they are used for comparative purposes. As I found in the VRI study it may not be possible to construct particularly relevant and comparable scenarios.

4.4 Modeling of Behaviour

There appear to be no adequate models of behaviour in terms of forecasting behavioural patterns. One way of avoiding this is to assume that behaviour will remain constant. However this is unsatisfactory as I found in the VRI study.

4.5 Conclusion

These lessons led me to look in more detail at forecasting, what is it? and why is it done? In the second part of my thesis I will look at forecasting problems, why forecasting is required in the planning/policy making process, and the implications of the problems for planning.

5. FORECASTING

5.1 Introduction

In this chapter I shall explain how forecasts are made [1]. The chapter starts with a review of forecasting which gives definitions of some of the terms I use, and an outline of the processes used. Following this I shall describe how models are used in forecasting, the inputs to them and how they are constructed. I shall conclude the chapter with a description of the general assumptions involved in forecasting. In the next chapter I shall deal with some of my criticisms of forecasting.

5.2 Review of Forecasting

Definition of terms

In the forecasting field there appear to be as many definitions of commonly used terms as there are writers on the subject. The definitions they give are not always consistent with one another. Many authors (particularly those who make forecasts as opposed to those who write about forecasting) have no clear idea as to the difference between such terms as:

Forecast
Projection
Prediction
Scenario
Extrapolation

Rather than make a long review of definitions of terms I shall just quote

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[1] My description is of the general processes used. It is not concerned with detailed mathematical techniques such as those developed by Box and Jenkins (1970).

some of those used by Jantch (1967).

> "The following terms have been adopted because (a) they are simple and comprehensive, (b) they correspond to the actual pattern existing today at the operational level and, therefore, (c) best serve the purpose of this report. They are not intended as rigorous definitions and no claim is made for their universal applicability. . . .
>
> A forecast is a probabilistic statement [2], on a relatively high confidence level, about the future. A prediction is an apodictic (non-probabilistic) statement, on an absolute confidence level, about the future. An anticipation is a logically constructed model of a possible future, on a confidence level as yet undefined. . . . 'The future' referred to in these notions includes situations, events, attitudes, etc." (Jantch 1967)

It is upon the above which I base the following definitions which I shall use in this thesis.

A forecast is a statement about the future which its author puts forward as having a high probability of being true.

A prediction is a statement about the future which its author is certain will be true.

A scenario is a logical model of a possible future with no specified probability.

An extrapolation is the result of continuing a past trend into the future.

A projection is much the same but can also refer to a wider view of the future, such as a scenario which was constructed from a consideration of past and current events. I shall only used the term projection where it is clear from the context the meaning which I attach to it.

One of the difficulties I have in selecting words to describe what I mean is to find a word which describes any process of making statements

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[2] "European readers, by association with 'weather forecast,' sometimes think of a forecast in the same sense as has been adopted here for a prediction. A weather forecast is usually given in the form of a prediction in Europe, but as a probabilistic forecast-'80 per cent probability of rain'-in the United States and Canada." (Jantch 1967)

about the future. The word which seems most appropriate is forecasting. However this can be confused with the narrower definition which I have given above. Where necessary I shall make clear which of these two meanings I attach to the word forecast.

Accuracy and Reliability of Forecasts

Before describing how forecasts are made I shall first give my views on the accuracy and reliability of forecasts.

After the event forecasts can be taken as predictions and compared with the actual outcome. Accuracy is then a measure of the closeness of the forecast to the outcome. Before the event it is not possible to say anything objective about an individual forecast. However it may be possible to say something about the process or method used.

The accuracy of a forecasting model can be judged by how well it explains past behaviour and that of a forecasting process can be judged by the accuracy of past forecasts (of events which have since occured) made using the given process. It is possible to make judgements of particular forecasts or models or processes in terms of subjective prior probabilities. However there is no necessity for my perception of what is accurate to be the same as anyone elses.

My view on reliability (of a set of forecasts) is that it is a measure of the accuracy of a set of forecasts. For example, a set of forecasts in which some forecasts were very inaccurate while others were not, would be less reliable than one in which all the forecasts were reasonably accurate. Reliability applies to a set of forecasts, or to a forecasting method.

I shall make no attempt to quantify either accuracy or reliability. However if I were to do so, I would start from the basis that they were related in the following way.

$$R = \sum_{i=1}^{n} (1/e_i)^2/n$$

Where R is the reliability of a set on n forecasts whose errors were e_i.

Reliability and accuracy can only be measured and talked about "objectively" after the event(s) forecast have occurred. Before this time any use of these terms must be subjective, that is they are the opinion of the person making the comment.

Forecasting errors can only be measured objectively after the forecast event has occured. Error is the difference between forecast and outcome. It can only be numerical if the forecast is numerical. If the forecast is that an event will/won't happen then there can only be error/non-error.

How forecasts are made

In general all types of forecasting, prediction etc. use the same basic process. This can be summarised as a model (of the system in question) into which data is input, and from which a result is output (see Figure 5.1).

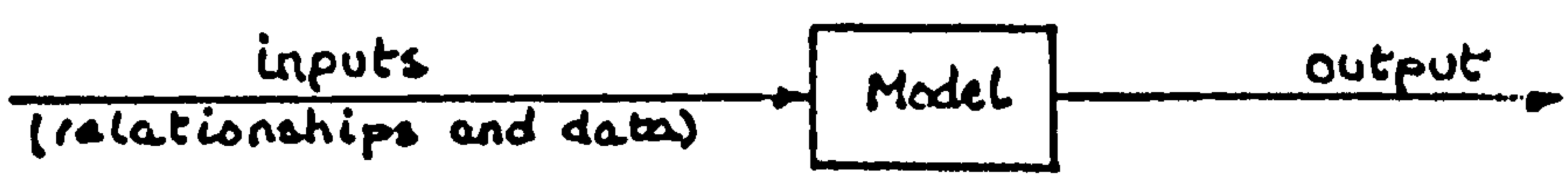

Figure 5.1 Basics of a forecasting model

The model may be no more than an observed correlation between two variables (such as primary energy demand and gross domestic product), or it may contain many relationships between many variables some of which are input (exogenous) and some of which are determined by the model (endogenous). An example of the latter type of model is that of Energy supply and Demand used by the Department of Energy (1978). There are also a whole variety of models which lie between these two types, of varying degrees of complexity.

The data which is input to the model is of two basic types. These are data used for calibration and that used for projection. For example in the case of the energy demand/GDP model past data on primary energy demand and of gross domestic product for a number of years are used to calibrate the equation used in the model, then projections of GDP are used in the model to get the corresponding projections of energy demand.

5.3 Forecasting models

To make a forecast it is necessary to have a model which covers all of the "relevant" variables. In this context I take "relevant" to mean all the variables which have a significant effect on the variables being forecast. However due to limitations in mans' ability to comprehend complex systems, any model will be an abstraction of the ~~salient~~ supposedly features of the system of interest.

All models exclude factors which could affect the result/output. However the model builder assumes that all factors which he excludes from his model have a negligible effect. That is he assumes that such factors can be neglected without loss of accuracy. He must also assume that the effect of such factors will remain negligible.

There are several ways in which models vary. Some of these are due to:

the level of disaggregation used;
whether the relationships modeled are causal or not;
whether the model is static or dynamic;
and whether the model is deterministic or probabilistic.

The sections below cover these aspects.

Level of disaggregation

The example given above of an energy demand/GDP relationship used in a forecasting model contains no disaggregation. To improve the "accuracy" [3] of the model, energy demand could be disaggregated by sector (such as Domestic, Industry, Transport and Other) and the demand could be related to the activity in each of these sectors. A further disaggregation could be made by splitting the demand for energy in each sector by the type of fuel used (such as Coal, Oil, Gas, Electricity) and

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[3] The degree to which the model represents reality. That is how well it could (in the view of the model builder) give a true reflection of the effects of different conditions/possible futures.

relating the demand for energy to useful demands (such as heat, light and work) rather than primary energy. A slightly higher level of disaggregation than this is used in the Department of Energy's (1978) forecasting model, and by Chapman et al (1976).

Disaggregation may improve the accuracy with which the model matches historical data, however it does require consideration, and usually projection, of many more variables to arrive at the desired forecast. In the above example of a disaggregated energy demand model instead of making a projection of one variable (GDP) projections of maybe 30 to 40 variables (activity levels in 4 sectors, 4-6 primary to fuel conversion efficiencies, and about 10 fuel to useful energy conversion efficiencies, plus the market shares of the four fuels in the four sectors) would have to be made.

Causal relationships

Another way in which models vary is whether the relationships in the model are causal relationships or not. For example the relationship betwen primary energy demand and GDP is not a causal relationship whereas a relationship between the heating requirements of a building and the inside and outside temperature is causal. The difference is that the first relationship is only based on historic observation whereas the second is also based on theory [4]. (In this case the theory is Newton's Law of Cooling which states that the rate of heat loss is proportional to the temperature difference between an object and its surroundings).

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[4] My model of the development of "Scientific Knowledge" goes some thing like:

(a) recognition of pattern in observations
(b) construction of models/hypothesis to account for/explain patterns
(c) testing of hypothesis
(d) conversion of hypothesis to Theory.

So the difference between "historic observation" and "theory" is one of how far the above process has progressed. However for any events which are not repeatable the process can not be taken beyond stage (b).

These two examples lie near the two ends of a continuum. There are also cases where the causes of a relationship are partially known. For example a relationship between useful energy demand and a sector's level of activity can be considered to be mainly causal. However there are, or may be, other factors which could also affect the level of useful energy demand. These include the mix of outputs of the sector and the mix of processes used. In general a single process will have a fixed relationship between useful energy demand and output, so the extent to which demand and output are causally related in a sector will depend upon how similar this relationship is between the different processes used and its mix of such processes.

In general the more disaggregated a model is the more likely it is that the relationships will be causal. Consequently a more aggregated model is less likely to have causal relationships. There are advantages of having causal relationships in a model in that it is easier to see if the relationships, and so the validity of the model, are likely to persist over time. However there is often the disadvantage noted above of increased complexity caused by disaggregation.

Static/dynamic and deterministic/probabilistic models

Cross (1975) following the presentation of Wilson (1968) identified two types of differences between models. These are whether the model is static equilibrium or dynamic and whether it is deterministic or probabilistic. This gives rise to four different types of model.

(a) Deterministic static equilibrium model. In this model the system is described at a particular time by sets of equations which can adequately represent the existing system. It is deterministic in that for a given set of input variables a unique model is defined. It is a static equilibrium model in that there is no provision for making the model evolve with time. However, input variables appropriate to a future epoch may be used to define a future state assuming the same equilibrium model remains valid.

(b) Probabilistic static equilibrium model. This model is similar in structure to (a) but now the relations are acknowledged to have a range of uncertainty. For a given set of input parameters, the model predicts a range of values for each output variable. To each value a relative probability can be assigned.

(c) Deterministic Dynamic Model. This type of model explicitly includes time as one of the variables. Thus, in contrast to (a) where it is assumed that the system adjusts itself rapidly to the equilibrium situation, here the dynamic behaviour of the individual components of the system are explicitly included. The model is again deterministic in the sense of (a).

(d) Stochastic Dynamic Model. This is similar to (c) but now uncertainties are explicitly included in the input relations and their dynamical behaviour. A range of models of the future systems are produced with assigned probabilities consistent with uncertainties in the model of the system. (Cross 1975, p28)

Most forecasting models are deterministic and most are also static equilibrium so that the large majority of models fall into category (a) above.

5.4 How Forecasting Models are Constructed

There are two general stages in the construction of a forecasting model. The first is the composition of its structure and the second is its calibration which may or may not include verification.

Composing model structure

There would appear to be no hard and fast rules about the construction of a forecasting model. Having said that though there are usually two stages involved. In the first stage components of the system to be modelled are identified and in the second the relationships between the parts or variables are determined.

The number of variables involved in the model and the level of disaggregation will depend on several factors. These include the resources available to construct and use the model, the required "level of accuracy" of the forecasts, the level of understanding of the model builder of the systems he is modelling, and the desired comprehensibility of the model. More resources, higher "accuracy" and more understanding will (in most cases) tend to lead to the use of more variables and greater disaggregation. However this also tends to lead to a less comprehensible model.

There is a continuum of possible sources for the relationships in models from well established laws through theories, hypotheses, to empirical studies. Beyond empirical studies there is more or less well informed speculation. The use of empirical studies covers a wide field which includes time trend analysis (using such techniques as those developed by Box and Jenkins (1970)), multiple linear regression, etc.

Some relationships may be omitted from a model on the assumption that the relationships will not change over the forecast period and so will have no effect on the forecast.

Assumptions made in constructing a forecasting model

There are three broad areas in which assumptions are made when constructing a forecasting model. These are about the scope of the model, the continuity of relationships over time and the constancy of social "values" and "preferences" over time.

It is generally assumed that all of the variables or factors which might have a significant effect on the variable being forecast have been included in the model. As mentioned above it is possible that a relationship between variables is not be included on the assumption that it will not change over the forecast period.

The second area in which general assumptions are made is that of continuity of relationships. The relationships in the model are either assumed not to change over the forecast period, or it is assumed that if they do change it will be in known ways which are built into the model.

Many of the relationships in forecasting models are dependent upon social "values" and "preferences". For example there may be a preference for foreign holidays in the sun rather than holidays in the UK. This preference will have an effect on holiday traffic forecasts both on destinations, inside or outside the UK, and mode of travel, car or aircraft. In general it is assumed that changes in "values" and "preferences" can be left out of forecasting models.

Calibration

There are two possible points at which the relationships in a model may be calibrated. These are either when the relationship is derived, i.e. if it is derived empirically for example from time trend analysis, or the relationship is fitted to historic data after it has been derived. If the relationships in a model are fitted to historic data it is usually by some type of regression analysis because in general there is more data than unknowns. However some times the reverse is true and it is necessary to make up the shortfall of unknowns over historic data from theory or more or less well informed speculation

5.5 Inputs to forecasting models

As illustrated in Figure 5.2 there are three types of input to a forecasting model.

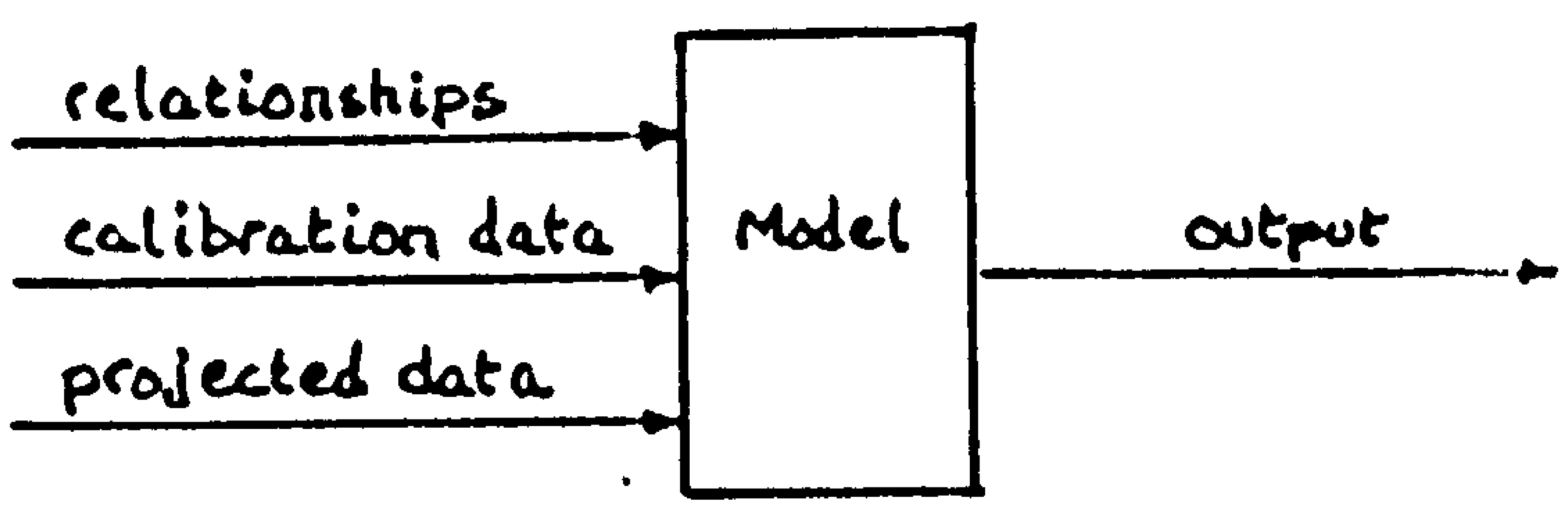

Figure 5.2 The three types of input to a forecasting model

These are:

(a) the assumptions (explicit or implicit) made about the relationships in the model and its structure;

(b) the data used to calibrate the model;

(c) the projected values of exogenous variables used to get a forecast. (In the case of a dynamic model there may be no exogenous variables in which case there would be no projected inputs.)

When a relationship is included in a model various assumptions are made. A relationship in a model may be derived from a well established theory, or from past observation, or from an unestablished hypothesis. In each of these cases the assumption is made that the relationship does hold and that it will continue to hold in the future. Another assumption that is made is that all of the relevant variables have been included in the relationship.

Having determined the structure of a model and the relationships in it, it is necessary to calibrate the relationships. That is to find numerical values for any constants in the relationships.

The final input to a forecasting model is of projected future values for exogenous variables. Specifically these are required for static equilibrium models. For example to obtain a forecast of primary energy demand using a simple energy demand/GDP model it is necessary to make projections of GDP over the period for which the forecast is required.

I shall say more on the possible sources of projected data below.

Classification of inputs

Each of the inputs to a forecasting model, as described above, can be classified as being either historic, or an extrapolation, or target, or from another forecast. This classification is illustrated in Figure 5.3 and is described below.

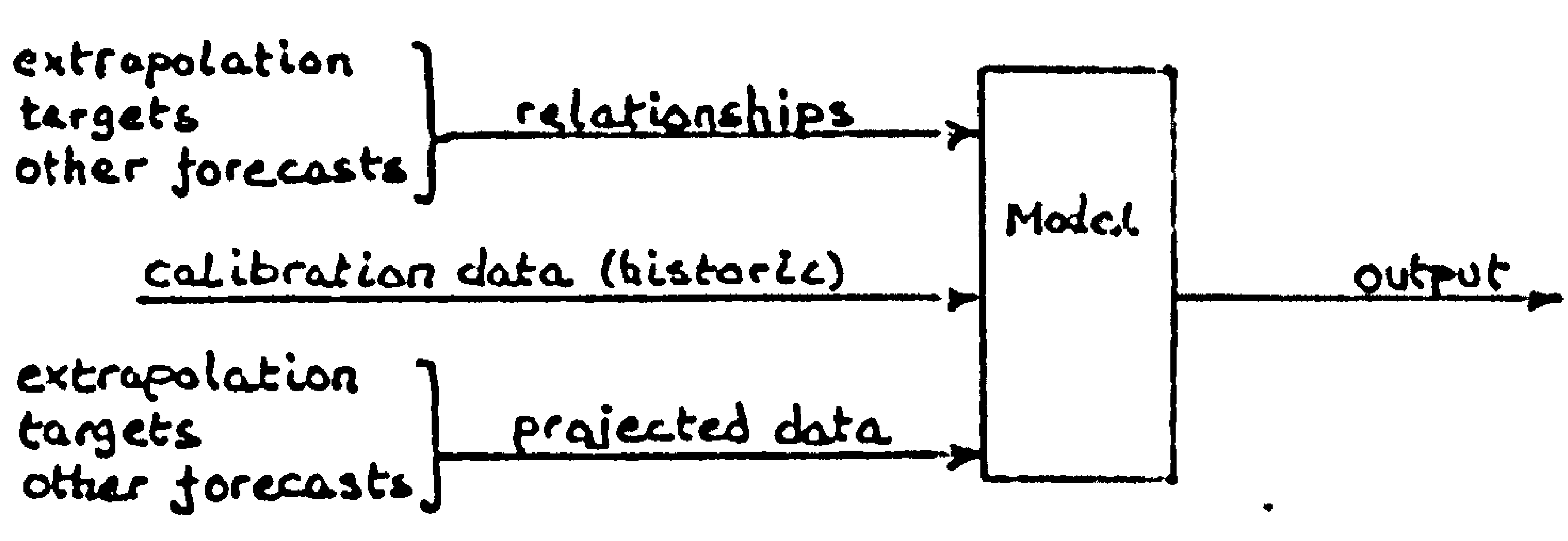

Figure 5.3 Origins of the inputs to a forecasting model

In the case of calibration data the only source is historic data. Due to the finite time it takes to collect data on what is happening now, it is not possible to know what is happening now, but only what has happened in the past (up to some point near the present). Consequently the only data available to calibrate a model is historic data.

There are three possible sources for the projected data input to models. These are extrapolations of past trends, targets or other forecasts. If an input to a model is projected on the basis of a relationship with other variables, either this relationship can be considered to be a part of the model, in which case it is the "other" variables which must be projected for input to the model, or the projection of the variable on the basis of the relationship can be considered to be a forecast its self, in which case the projected input is the result of another forecast. In either case the ultimate inputs are made upon the extrapolation of past trends. That is, at some point recourse is made to the argument that, "for this variable we shall assume that its observed past behaviour will continue into the future". This is often made without any underlying reason. In many cases the past behaviour of the variable is that it has remained constant and it is assumed that it will continue to be constant in the future.

The second possible source of projected data for input to models is targets. For example one of the inputs to a model might be GDP, and rather than making an extrapolation of GDP from past trends or using a projection from another forecast, the values input may be targets. To the extent that targets are used as the inputs to a model the resultant forecast is normative rather than positive. That is, it is made on the basis of what the forecaster (or those he is forecasting for) wants to happen rather on the basis of what he thinks will happen.

The use of a target[5] as an input might be to determine the effects of reaching a target, or it might be to determine the necessary prerequisites of reaching a target, or it might be used on the assumption that the target will be reached. In the latter case the target is effectively being used as another forecast.

The third source of projected data for input to models is from other forecasts. More is said, about this source below.

[5] Within the model the target will be treated as a constraint.

Like projected data there are also the same three sources for relationships in the model. In most cases the relationships in a model are extrapolations of relationships from the past. This extrapolation is usually that the relationship will be the same in the future as in the past. However some times a relationship has been changing in the recent past and this change in the relationship is projected into the future. The use of targets or other forecasts as the source of relationships is less common. It happens most often in dynamic models where the only way in which the results of the model can be changed is by changing the relationships used.

The three sources of input for relationships and projected data are illustrated in Figure 5.4.

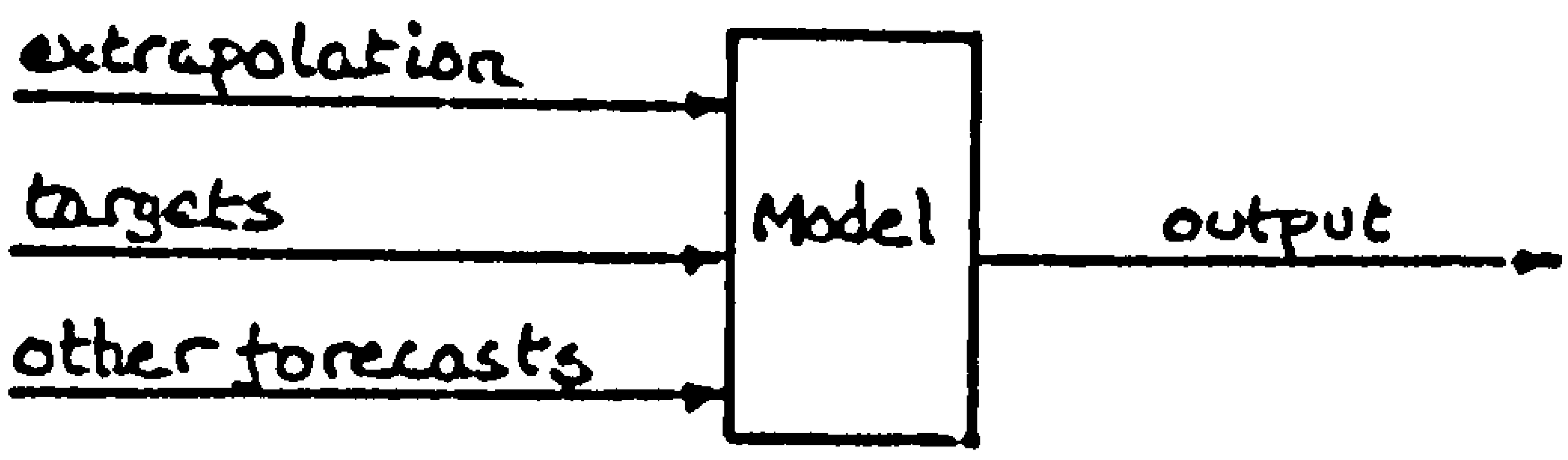

Figure 5.4 Basic inputs to a forecasting model

However since the inputs to all other forecasts also consist of these three sources there are only two independent inputs to the forecasting process in general. These are extrapolations of past trends and targets, as illustrated in Figure 5.5.

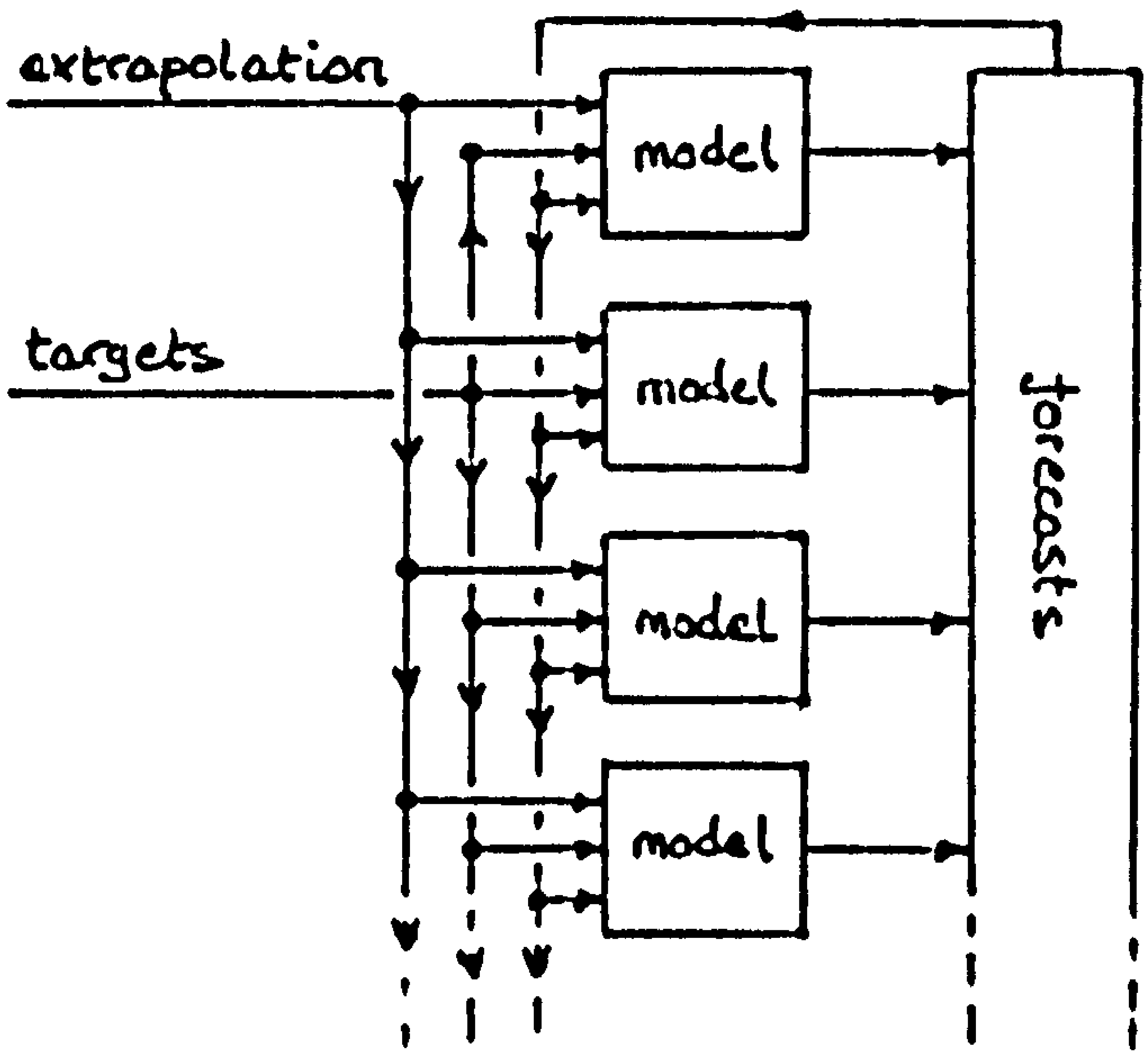

Figure 5.5 Exogenous inputs to forecasting

5.6 Summary

In this chapter I have covered some of the terms used in the literature on forecasting as well as making a very brief review of the literature. I then went on to describe the way in which models are used in, and constructed for, the forecasting process. In the next chapter I shall describe some of my criticisms of the forecasting process.

6. CRITICISMS OF FORECASTING

6.1 Introduction

Following the outline of forecasting methods in the last chapter I shall go over some of my criticisms of forecasting in this chapter. Most of my criticisms are due to forecasting models not living up to my ideal. My ideal forecasting model would be one:

(a) in which relationships are based on scientific or engineering laws

(b) in which assumptions are external to the model or at least changeable

(c) in which the model is as disaggregated as the data available permits so as to allow the sources of variability/variation to be identified (so that they can be forecast instead of being hidden).

(d) which is as comprehensive as the resources available permit

(e) in which data reliability is made explicit.

In the process of setting out my criticisms I shall use examples of forecasts mainly in the transport field. My criticisms are in three areas, which are to do with forecasting models, the data input to these models and other criticisms. (The main forecasting exercise which I shall use for examples of the criticisms is Tanner (1974). This is not because I think that it is a particularly good or bad example of forecasting, but because of its very explicit explanation of what was done, it illustrates most of my criticisms) [1].

6.2 Forecasting models

I shall make criticisms of forecasting models in three broad areas. These are the level of aggregation used, the relationships used in the models and the data used to calibrate the models.

Level of aggregation

I shall show that one of the ultimate points in the forecasting process is the extrapolation of trends in variables. If a composite variable is not homogeneous it may well be that its several components display different trends over time. However by using the aggregate of these components this variation will not be seen.

An example of the problems caused by using an aggregate measure model is the tonne-kilometer/GDP relationship used by Tanner(1974) to forecast freight transport. Having said that " . . . goods vehicles . . . contribute substantially to traffic and . . . give rise to particular policy issues, and must therefore be carefully studied" (Tanner 1974, p9), he develops a very simple model. He justifies this by saying " . . . it would have been preferable to use a method that gave forecasts disaggregated by vehicle weight or load. However understanding of how factors which influence lorry size will operate in the future is insufficient for this to be done with any confidence" (Tanner 1974, p24). He also recognises that the tonne-km/GDP relationship may change due to increasing services as a proportion of GDP, environmental restrictions on Road Transport leading to shorter

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[1] One of my problems when writing this chapter was in saying what the effects of my critisisms are. I have since realised that this was because I had not erected any criteria upon which to judge forecasts. It now appears to me that forecasts cannot be judged independently of the purpose for which they were made. To me (now, as opposed to when I wrote this chapter) the only criterion on which it is sensible to judge a forecast is: "How well does it serve its purpose?" Unfortunately it is now too late to incorporate this criterion into this chapter. Apart from anything else it would first be necessary to specify which of many possible purposes that I was judging Tanner's forecasts against.

hauls and technological improvements leading to lighter weight per unit of GDP. However he concludes "analysis of these possibilities in terms of particular industries or commodities is beyond the scope of this report" (Tanner 1974, p25).

Having made forecasts of the tonne-km of freight carried by road he goes on to use this in conjunction with a projection of average carrying capacity of vehicles to get a forecast of road freight vehicle kilometres. However due to the aggregate nature of his forecasts he takes no account of changes in the distribution of vehicle size within the vehicle stock. He further goes on to make a projection of increases in kilometres travelled by each vehicle without considering the relationship between vehicle size and kilometres travelled.

The advantages of using an aggregate model are that the model is easy to construct and callibrate, and that few inputs are required. However aggregate models suffer from the disadvantage that they obscure relationsips within the system under study. Consequently it is not possible for the forecaster (or others) to be sure if the model will continue to be reliable in the future, since the underlying relationsips may change.

Relationships

There are at least four ways in which the relationships used in models can be criticised. These include having no causal explanation for a relationship, the use of cross-sectional relationships, the exclusion of relevant variables and lack of understanding.

If there is no causal explanation for an observed relationship there can be no way of knowing if the relationship will continue in the future. As an example of a relationship used without causal explanation (Tanner 1974, p9) assumes "that the total of all . . . elements of cost [for cars, other than fuel] will, in real terms, decrease by 1 per cent per year from 1972 onwards" on the basis of observed trends over the period 1952-1972.

A further example is the extrapolation of a trend in goods vehicle load factors by Tanner (1974, p31) without any understanding of the underlying causes of the historic trend.

In many cases where data on a relationship between variables is not available over a period of time (longitudinal) the relationship is defined for subgroups (such as income bands and geographical areas) at one point in time (cross-sectional). For example as a justification for using a car kilometre/average income relationship Tanner (1974, p16) uses relationships found from the 1972-73 National Travel Survey (Department of the Environment 1974b). He finds a positive relationship between income and kilometers per car. However the relationship found "may be influenced by factors such as residential location and life style and may therefor overestimate the true effect of income" (Tanner 1974, p16). In this example there is no guarantee that the cross-sectional relationship will be the same as the longitudinal relationship because it would imply increasing average income leading to, or at least being associated with, changed average "residential location and life stile". In general cross-sectional and longitudinal relationships can not be assumed to be the same.

For simplicity in a forecasting model variables which have an effect on the variables being forecast are often excluded. Examples of variables which Tanner (1974) did not consider in his car ownership forecasts were population density and public transport provision.

Cross (1975, p41) makes the following comment on forecasts of car ownership in the London Traffic Survey (Greater London Council 1966): "A real relationship has been found for the year 1962 between residential density and car ownership and it is independent of income. The forecasters reject this in favour of a model which is much more sensitive to net household income and thus capable of giving any result desired by relatively small adjustments in the rate of increase of the G.N.P. Do the forecasters imply that they do not believe the relationship including residential density or that it is insignificant?"

There would appear to be many instances in which there is a basic lack of understanding of the processes which influence variables being forecast. Several examples of lack of understanding are displayed by Tanner (1974). For example he relates car use to cost. "Although it is usually argued that travel behaviour is influenced by generalised cost, including travel time, it is not plausible to suppose that increases in generalised costs due to higher incomes and therefore higher valuations of car travel times will lead to lower car ownership levels; one expects the reverse to apply. . . . In this report calculation are made in two ways, with and without a valuation of travel time; fortunately, because of the calibration process employed, the alternative methods give rise to very similar forecasts" (Tanner 1974, p10) (emphasis added).

In his forecasts of bus transport he does not consider the effects of variations in incomes or fuel prices because it is not "clear how the figures would be affected by alternative assumptions about trends in incomes or fuel prices" (Tanner 1974, p23). He also finds difficulty with motor cycles. Having commented that there is "no obvious basis for estimating an ultimate or saturation level in the distant future" (Tanner 1974, p19) he uses a continuation of the current ownership level and annual mileage. He further comments "no suggestions are made as to how the figures might respond to alternative cost or income assumptions" (Tanner 1974, p22).

Data and calibration

The "accuracy" of a forecasting model depends upon the reliability of the data used to calibrate it. (This is assuming that the relationships in the model are "accurate".)

There are several ways in which the data used for calibration may be inadequate. These include the absence of data on a variable (in which case a surrogate is often used), incompatible data classification and different values for data between sources, insufficient data for calibration and finally the data may not fit the model. Examples of all these problems can be found in Tanner (1974). Perhaps a more serious problem is the accuracy of the data used.

Tanner (1974) relates car ownership to GDP but comments "It can be argued that disposable personal income or consumers' expenditure would be more relevant to car ownership and use, but there is some doubt about this and the use of a quantity that includes more than the personal sector has been preferred" (Tanner 1974, p4).

In considering annual milages of cars Tanner (1974, p18) considers the effects of improvements to the road system but uses the length of motorway open as a "road quality factor".

The data Tanner (1974, pp 2,3) uses on vehicle populations and vehicle milages are not compatible due to differences in the classifications of vehicles used in the two sources of this data. He also notes differences in data on numbers of cars per household from two different sources.

An example of insufficient data for the calibration of a model is Tanner's exclusion of changes in travel speed from the calculation of the time component of generalised cost because "insufficient data exists to allow this to be done" (Tanner 1974, p10).

If there is empirical data which will not fit into a forecasters analytic model he may be tempted to ignore it. For example, in a regression analysis of increase in car ownership per year against car ownership, Tanner (1974, p61) excludes data for Scotland. This is probably because its inclusion would give a meaningless intercept, and greatly increase the standard error.

Consideration must also be given to the accuracy of the data used to calibrate a model since the model can be no more accurate than the data. The following outlines some of the ways errors can creep into statistics. There are many others!

> "From the time when figures are first entered on a form in a local Government or business office, until the statistics are published in statistical volumes and reports, data processing is highly sensitive to many mundane sources of error - misunderstood instructions on forms, misreading of hastily written figures, misplacing a decimal point, losing one's place in copying, accidental 'corruption' of data in computer files, or printing errors. It is quite possible for a mistake anywhere along the line to go undetected and work its way through into published figures. Once in a while such a case emerges into the glare of publicity, giving newspaper cartoonists a chance to re-use their civil servant caricatures.
>
> One example was when, following the accidental omission of a zero by an Olivetti employee reporting the firm's exports, an under-estimate of national exports (and thus on overestimate of the excess

of imports over exports) generated a phoney balance of payments crisis. Another was when the trade figures went haywire over a period of many months because a clerk at one point copied two lines of figures onto a coding sheet in the wrong order. (The first assumption, as reported in the press, was that it was the fault of an excessively complex computer programme for carrying out seasonal adjustments on the figures.) A major error in Home Office migration figures resulted from accidentally counting the same set of movements twice" (Government Statisticians' Collective 1979, p144).

6.3 Input data to forecasting models

Criticisms of data input to models in forecasting can be made in the following areas: the reliability of the inputs, the use of other forecasts, the ultimate sources of input data, and the limited ranges used when varying input variables.

Reliability of inputs

The reliability of a forecast is closely related to the reliability of the inputs to the forecasting model used. Just as with any other type of model the well known phrase "Garbage In - Garbage Out" applies to forecasting models.

Other forecasts

As explained in the previous chapter one of the inputs to forecasting models are other forecasts. This is often done with little consideration of the original forecasts used. For example Tanner (1974) uses population projections made by the Office of Population Censuses and Surveys (1974) as population forecasts, with no consideration of them, other than to note that between projections made in 1971 and 1974 there was a fall of 8% for the 2010 population. Another example is that having said that in forecasting Gross Domestic Product he "makes what can be little more than guesses about the future" Tanner (1974, p4) uses Organisation for Economic Cooperation and Development (1972) Expenditure trends in OECD countries 1960-1980 (which he calls long term forecasts) as the basis for the GDP forecasts he uses.

There are several dangers in using other forecasts. There are three possible events which could affect the result of the forecast being made. The first is that there can be a circularity of inputs. For example a series of economic forecasts could be used as inputs to a series of transport forecasts and vice versa. If this does happen the exact nature of the interaction between the two sets of forecasts may not be apparent. The second is that all of the assumptions of the forecast used as an input will implicitly be included in the forecast being made (as will any errors). The third is related to the second and is that assumptions made in the input forecast may be inconsistent with those used in the output forecast.

Finally there is a danger in using targets as forecasts. For example commenting on sources of error in forecasts of car ownership in the London Traffic Survey (Greater London Council 1966), Cross (1975, p 40) comments: "Probably the most important sources of error is the assumed value [sic] of the Gross National Product at 4% for the period 1962-1981 (Vol. II, p26). (This appears to have been an acceptance of the National Plan figure which was an overestimate if it is accepted as a forecast not a target.) This charge is of major importance since car ownership is shown to be a sensitive function of mean household income."

Ultimate sources of input data

The other independent input to forecasting is the extrapolation of past trends. Often these extrapolations are no more than guesses. In some instances variables are assumed to remain constant in the future. An example of this is that Tanner (1974, p18) considers that his road quality factor (the amount of motorway per 1000 cars) "will remain at the 1972 level." In other cases past trends are extrapolated. For example Tanner (1974) uses extrapolations of modal splits between road, rail, water and pipeline freight distributions without any consideration of the underlying causes.

Often trend projections are acknowledged to be guesses. We have already seen that in considering GDP Tanner (1974, p4) " . . . makes what can be little more than guesses about the future." However guesses are often obscured. For example " . . . price levels [for liquid fuels] have been chosen . . . to give some indication of the effects of the future price levels at present being suggested [by others]" (Tanner 1974, p 9).

Limited range of input variables

One way of acknowledging the basic uncertainty of the future is to use probabilistic models. However these are difficult to construct. A simple way of overcoming this problem is to use a range of input values in a deterministic model. This is the approach adopted by Tanner (1974). He uses a range of values for "elasticity", GDP and fuel costs but not for others such as population and saturation level for car ownership. "There are considerable uncertainties about various other aspects of the methods and data; these include the concept of a car saturation level and the value used for it, the population forecasts, the implicit assumptions that certain past trends due to unquantified factors will continue, and the policies that future governments will adopt towards road building, restraint and public transport. No attempt is made in this report to give a range of forecasts to cover alternative assumptions about such matters" (Tanner 1974, p 35). The effect of this is to give a narrower range of forecasts than would result if all input variables were varied.

6.4 Other criticisms

Other than criticisms of forecasting models and of the input data used, I have an assortment of other criticisms. These include criticisms of assumptions made about the continuity of relationships over time, other assumptions which are made, the self-fulfilling nature of some forecasts and the lax use of terminology.

Continuity of relationships

The most common assumption found in forecasting models is that the relationships built into the forecasting model (which are usually based upon past behaviour) will continue in the future, or will change in some known or predictable way. However it is precisely because the future is conceived of as being different from the past that forecasts are needed. The only justification for making this type of assumption is that the forecaster perceives there being less chance of change in the relationship he holds to be constant than in what he is forecasting. The consequence of this is that any forecast is the product of the subjective judgement of the forecaster. There can be no objective forecasts.

A further problem with relationships used in models is that they are often assumed to be valid outside of the range within which they have been observed.

"A model can be only as good as its initial assumptions - a model based upon unrealistic assumptions will produce unrealistic answers . . . [It is always necessary to] . . . ask . . . to what extent . . . assumptions are justified. For example is it reasonable to extrapolate an estimated relationship into situations which have not been observed (That is, to use the relationship when the independent variables take values much greater or much smaller than those found in the sample which was used to estimate it)?" (Robinson 1972b, p159)

As an example of a relationship which was assumed to continue in the future it is interesting to look at that between tonne-km and GDP. To make forecasts of freight transport Tulpule (1972) finds and uses an approximately constant ratio between tonne-km and GDP. Only two years later Tanner (1974, p 24) claims to have found a fall in the ratio between 1970 and 1972. This he uses as justification for assuming a proportionality between increases in tonne-km and increases in GDP, with tonne-km growing at 2/3 of the rate of GDP. Tulpules assumption is that:

$$dTkm/dt = dGDP/dt$$

where as Tanners is:

$$dTkm/dt = 2/3 \ dGDP/dt$$

This illustrates the fact that trends between variables need not continue in the future.

Another example of the assumption of continuity of relationships is the assumption that past trends will continue, such as the previously mentioned trend in falling costs of owning and running cars.

Assumptions

Apart from the assumption of continuity of relationships many other assumptions are usually made in forecasts. Many of these are very arbitrary. Some examples from Tanner (1974) are given below (emphasis has been added).

" . . . some rather <u>arbitrary assumptions</u> will be made about the future [with respect to motorcycles]" (Tanner 1974, p 19).

In view of buses and taxis forming a small proportion of road traffic "and the various uncertainties <u>very simple</u> assumptions will be made" (Tanner 1974, p23).

"While it is difficult to see what is likely in the future, this growth [of freight transport] seems perhaps a little high [reference to Tulpule (1972)], and it is <u>felt</u> that lower rates of increase are appropriate . . ." (Tanner 1974, p 29).

"In the absence of any clear indication from the [previous] analyses, this report follows Tulpule's [1972] <u>arbitrary assumption</u> that the present ratio of light vans to lorries will be maintained" (Tanner 1974, p 33).

Self-fulfilling forecasts

There are many instances in which forecasts are self-fulfilling. For example the announcement of difficulties in say sugar supplies and the prediction that there will be shortages in the shops will at least exacerbate the situation if not actually cause the shortage.

Another example of the self-fulfilling nature of forecasts, is that having noted a relationship between the quality of the road system (measured in terms of length of motorway) and car use, Tanner (1974, p 18) assumes that improvements in the road system will keep pace with increasing car ownership. In his introduction Tanner (1974, p 2) says that his forecasts "reflect a view of how the future will develop. Others may disagree with this view, and no special authority is claimed for it."

However his forecasts were used as the basis of forecasts made by the Department of the Environment (1975c). These forecasts were used to justify the building of motorways, so helping to bring about the very thing which was forecast (increasing traffic).

Terminology

A final criticism of forecasting is that the use of terminology is often very loose. For example in various contexts Tanner (1974) uses the terms "forecast", "prediction", "projection", and "extrapolation of past trend" interchangeably.

6.5 Summary

In this chapter I have outlined some of my criticisms of the forecasting process. These were about forecasting models, their inputs and some more general criticisms of forecasting. Perhaps the majority of these criticisms can be summed up by saying " . . . the future, in fact, cannot be predicted, we cannot know 'the truth' about the future until it has occurred but we act as if we can foretell the future to some extent" (Chadwick 1978, p155). However I believe that this extent is limited and to pretend otherwise is to limit the range of futures open to us.

7. REVISED VIEW OF FORECASTING

7.1 Introduction

In this chapter I shall review some of the lessons which I have learnt from the case studies. The conventional view about forecasting [1] is that it is an "objective" process. However there are so many subjective inputs to the forecasting process that there is no way in which it or its results can be "objective". I shall talk about this in sections 7.2 and 7.3 below on input data and models respectively. Then I shall give some fundamental reasons why "objective" forecasts cannot be made, in section 7.4.

7.2 Input data

Referring to the description of the modelling process used in forecasting given in Chapter 5, there are three types of inputs to forecasting models. These are assumptions about relationships, calibration data and projected values for exogenous inputs. There are three sources for the projected exogenous inputs, which are extrapolation of past trends, targets and other forecasts. However as I explained in Chapter 5 only the first two are independent inputs to the totality of the forecasting process. They are dealt with below. I shall deal with the construction of forecasting models in the next section.

Projection of trends

At some point in the forecast modelling process a stage is reached at which no further causal explanations for the variables in the model are looked for. This can be for one of several reasons including the judgement that the underlying causes will not change over the forecast period or

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[1] That is the view of those who make and use forecasts within the policy process.

complete ignorance of the underlying causes and the assumption that they will not change.

In either of these cases the judgment of the forecaster is involved. Of its nature any such judgement must be subjective. There are two possible ways of making a trend projection. In the first some characteristic of the variable is assumed to remain constant such as its level or its first derivative (linear growth) or its growth rate (exponential growth). The assumption of constancy on the part of the forecaster involves his value judgement. The second way of making a trend projection is for the forecaster to use his judgement that such a characteristic will change over time. In this case his judgement is more directly evident. In either case the judgement of the forecaster is involved.

The judgement that the underlying causes will not change over the forecast period often goes with the belief that the underlying trend is desirable. If it were not believed to be desirable it is likely that the forecaster would find some mechanism whereby it might change.

Targets

By their nature targets are subjective. They are not "what is likely to happen" but what the forecaster or forecaster's client wishes to happen. Targets can either be judged to be realistic, that is that they will be attained, or they are part of a conditional forecast. Conditional forecasts are answers to one or other of the questions: "what happens if the target is met?" or "what is necessary for the target to be met?"

Subjective results

As shown in Chapter 5 the only independent inputs of exogenous variables to the forecasting process are trend projections and targets. As explained above both of these inputs are subjective. In consequence the output of the forecasting model will also be subjective. It is no more than the consequence of the subjective inputs. However I shall also show that the models themselves are also the result of the subjective judgement of the forecaster.

7.3 Models

Model Structure

As explained in Chapter 5 a forecasting model should cover all "relevant" variables. However the choice of which variables are relevant is made by the model builder. His choice of which variables to include (what is to be within the system under study) and what is to be excluded is arbitrary.

For non-causal models the choice of relationship form is made on the judgement of the model builder. Of more importance is his judgement, or even act of faith, that the relationship found in the historic data will continue in the future. This judgement requires the assumption that the underlying causes of the relationship will remain in the future or that if there are several causes for the relationship that a change in direction of one cause will be offset by a change in the opposite direction by others.

In causal models there is a similar judgement that the causal relationships modelled will remain constant over the time period of the forecast. In summary the models used in forecasting are arbitrary and subjective and consequently so are their outputs.

Historic data

The historic data upon which forecasting models are based (which is used for calibration) is poor. The outputs of these models will be of no greater reliability and in consequence will also be poor.

7.4 Fundamental Problems

At one level criticisms can be made of individual forecasts and forecasting models as was done in Chapter 6. It is at this level that the acknowledgement can be made that there are very great problems with forecasts which is often then followed by the statement "but we have to do something." At this rather superficial level it will never be possible to ensure that all avenues of enquiry into how forecasts might be improved, have been explored.

There is however a deeper level on which it can be shown that there are fundamental problems which can not be overcome by improved technique and which make objective forecasts impossible. These problems can be summarised as:

Ceteris Paribus paradox
Untestable hypotheses
People's value systems

Ceteris Paribus paradox

The reason models are used in forecasts is that it is believed that the past will not be like the future so the use of "simple forecasts" (ie future value of variable will equal current vaule) cannot be used. The models depend upon the Ceteris Paribus condition (that everything else will remain equal). However it is just because it is believed that things will change, that the models are used.

Figure 7.1 illustrates a system which is under study.

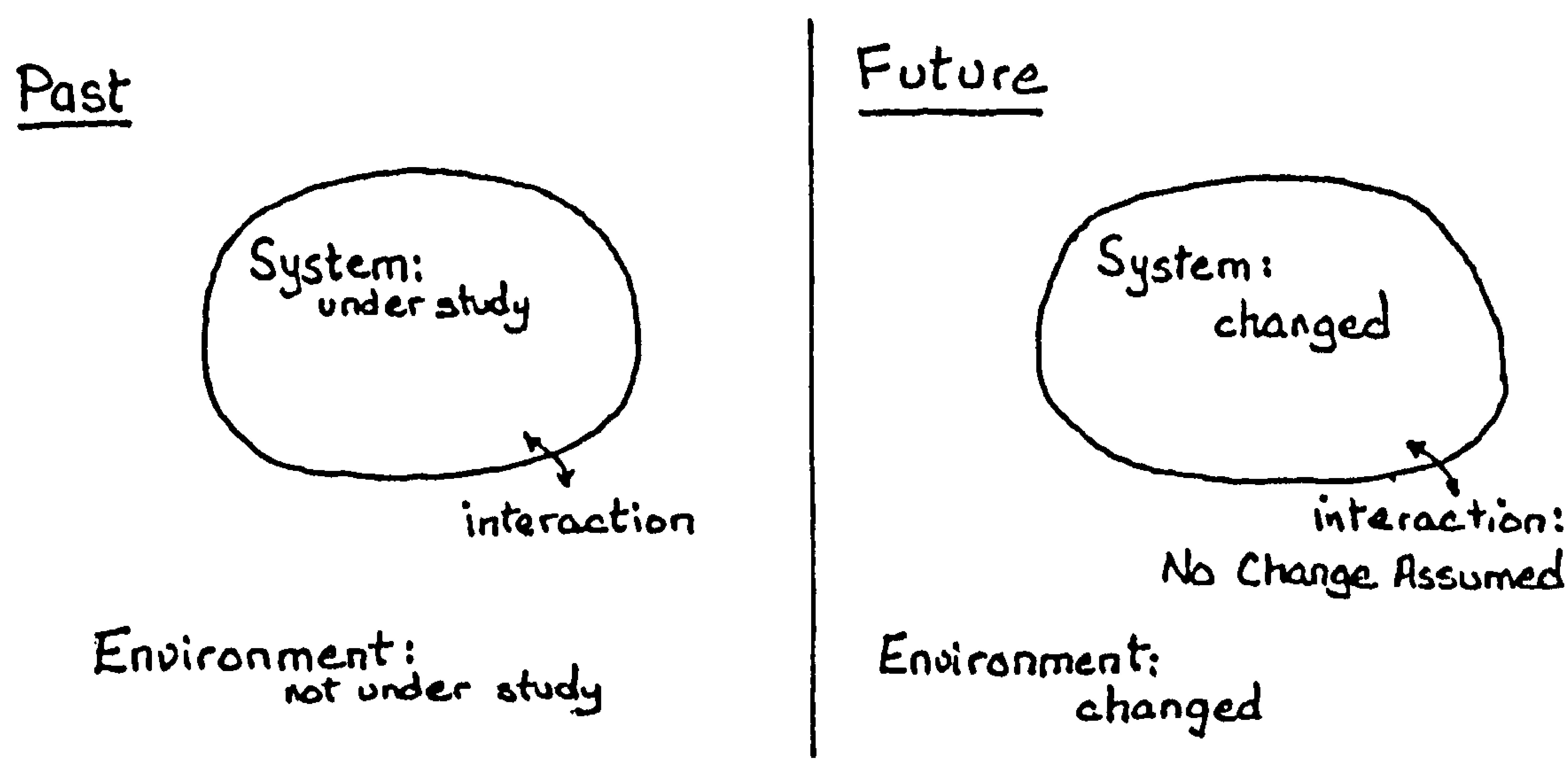

Figure 7.1 A system which is under study

If a forecast is to be made of a component of the system, the system boundary will probably have been drawn so that there is a minimum of interaction between that component of the system and the environment. However I shall redefine the system boundary to be coterminous with that of the model. Consequently everything which is modelled is within the system and everything which is not modelled is outside the system.

Both open and closed systems [2] can be modelled. However when open systems are modelled all interactions with the systems environment must either be known or assumed to remain constant. It is the later of these two which is known as the Ceteris Paribus condition (everything else remaining constant).

To me it is paradoxical that the two assumptions:

(a) Things will change

(b) Things won't change

are made whenever a forecasting model is used. The justification for doing this is that the forecaster is of the opinion that he has included all relevant things which will change in his model and that anything which changes outside of his model will have no significant effect upon it. However this is dependent solely upon the model builders judgement and can not be based upon any objective criteria.

Untestable hypotheses

The way in which hypotheses are used is that they are deemed to be true until evidence emerges that they are not true. The process of searching for such evidence can be considered to be testing a hypothesis. However such a search can not be guaranteed to be complete until such time as evidence for the falsity of the hypothesis is found. Ultimately the most the can be said of a hypothesis (or theory) is that "it is not known to be untrue", which is very different form the statement "it is known to be true".

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[2] In this discussion I shall not consider closed systems because none (or very few) occur in the forecasting/ planning field in which I am interested.

For a hypothesis to be falsifiable the conditions under which it holds must be repeatable. In general it is only in closed systems that conditions can be repeated since, by their nature, open systems can not be isolated from everything else which is constantly changing. The consequence of this is that hypotheses about open systems are in general unfalsifiable.

The result of this is that when facts emerge about an open system which do not agree with a hypothesis it is possible to find an explanation. This can be something which was not considered, either within the system, or within its environment.

The effect of this is that in any examination of the success or failure of past forecasting exercises, "reasons" can always be found for the failures.

People's value systems

One of the elements of any system being forecast within the policy formulation field is people. Unlike inanimate objects important properties of people change in unpredictable ways. These properties which change can be called "values".

People are involved in the systems being forecast and they act according to their value systems. However they can change their own value systems in ways which cannot be modelled. Consequently there are important aspects of any system being forecast which cannot be modeled. Basically because people are involved there are relationships within any forecasting model whose future can not be predicted.

7.5 Summary

In this chapter I have outlined my revised view of forecasting which is basically that objective forecasts are not possible and that there are severe problems in the whole of the forecasting process.

Even if forecasting models were objective representations of reality they would be no more than opinion transformation devices. The outputs of forecasting models can be no more than the consequences of the input assumptions. Given that the inputs to forecasting models are the forecaster's subjective opinion of what will, or might, happen in the future the output of the models will merely be a transformation of these subjective opinions. There is no way in which a subjective input could be converted to an objective output and there is also no way in which the inputs to forecasting models in the policy field can be objective.

The fallacious view that forecasts are objective is maintained by the use of highly complex mathematics through which many observers of the forecasts outputs can not see to the underlying inputs. However just as in computing the expression

Garbage In - Garbage Out

equally applies in forecasting.

8. PLANNING

8.1 Introduction

Having realised that objective forecasting was not possible, I thought that it would be fruitful to look at the reasons why forecasts are made. In this chapter I shall give an introduction to planning and examine why it needs forecasts.

I shall start the chapter with a review of some other authors definitions of planning. I shall then describe a framework in which the planning process can be considered. Following this I shall consider the things which lead to planning and then give some examples of areas in which planning is performed. I shall end the chapter with some descriptions of the planning process and an examination of why planning needs forecasts.

Definitions of planning

As noted by Cross (1975, p8) in a paper on Forecasting in Urban and Regional Planning: "The literature on the idea of planning as a means of social action is enormous. [I] can do no more than provide a very brief general introduction to the positions adopted and indicate how [I] have treated them. [Also] . . . there is no generally accepted concept of 'planning'."

However below are six definitions of the term "planning".

> ". . . planning is a process, a process of human thought and action based upon that thought - in point of fact, forethought, thought for the future- nothing more or less than this is planning, which is a very general human activity." (Chadwick 1978, p24)

> A ". . . literal meaning of the term [planning] . . . is an attempt at rationally calculated action to achieve a goal" (Dahl and Lindblom 1953).

"Planning has always meant taking intelligent, rational action. However, what constitutes intelligent action is the subject of much argument" (Faludi 1973a, p35).

A ". . . plan is distinguished from a set of projections or forecasts because it is constructed on the assumption that the behaviour of . . . agents will <u>not</u> be the same as in the past nor will the changes in their behaviour be due only to measures already introduced. The plan shows the effects of future changes which have not yet been made but which will have to be made if it is to be achieved" (Robinson 1972b, p122).

After giving 13 definitions of planning by other authors, Dror (1963) gives the following definition. "Planning is the process of preparing a set of decisions for action in the future, directed at achieving goals by preferable means."

"In one useful literal meaning of the term, planning is an attempt at rationally calculated action to achieve a goal. The attempt to achieve rational politico-economic action may therefore be described as economic planning whether the attempt employs the market or master mind. But economic planning thus conceived is so different from economic planning as . . . [other writers] . . . use the term that we shrink from what would otherwise be a convenient shorthand expression. Although we shall consequently use the term only when the risk of misinterpretation is at a minimum, the argument of the book may be thought of as an approach to a new concept of planning" (Dahl and Lindblom 1953, p20).

Elements which are common to most definitions of planning are that it is future orientated and that it is concerned with real choices. An element that appears in many definitions is that planning is orientated to action in the future. Implicit to definitions of planning is that it is (within the planners perception) about changing the system in question for the better.

8.2 A Framework in which to consider Planning

When I started looking at planning I wanted to find a general description of the planning process. One description which I found was Faludi's model of planning (Faludi 1973a). His model is based upon an analogy between how an individual perceives and acts upon his environment and how an organisation does these things. Faludi (1973a) said of it that "it explains planning phenomina by showing how they form part of a coherent whole, [and] it creates a language in which to converse about planning." His model of planning agencies "is based on an analogy between agencies and the human mind engaged in operational (purposive) thinking."

I had intended to present Faludi's model at this point in my Thesis. However after considering Faludi's model there were several aspects about which I was not happy. In consequence I have developed my own model which is based upon Faludi's. I have also incorporated ideas from a model of the human mind developed by Powers (1974). As well as being a useful way of considering why planning needs forecasting, I think it could form a very useful framework for the analysis of planning systems. I shall say more about why planning needs forecasting later in this chapter. I shall say more about using this framework for analyzing planning systems in the next chapter.

Some of the important elements in my model are that there is a hierarchy of control or decision units [1]. An example of a chain within the hierarchy of control over the building of a power station is shown in Figure 8.1.
I shall start by describing how a unit within the hierarchy of levels could work. In practice it might be difficult to identify the components of a unit with <u>things</u> within the organisation being modelled. However it appears to me that my model will behave in similar ways to that in which organisations do. I am presenting the details of how the components within a unit could operate to give an idea of how individual units <u>could</u> work. I am not suggesting that this is how they <u>do</u> work. By giving these details I shall develop a vocabluary which will be useful later.

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[1] In my model the hierarchy of control will usually correspond to a hierarchy within and/or between organisations. However this correspondence between structure and function is not necessary for the function to operate.

Cabinet

Department of Energy

Electricity Council

Central Electricity Generating Board

CEGB Planning

Plant manufacturer

Design staff

Forman

Worker

Figure 8.1 Hierarchy of control over power station construction

Simple unit within a control system

In a simple unit within a control system there are three elements as illustrated in Figure 8.2.
The first element is an input function. This converts inputs from the environment into a perceptual signal. The perceptual signal corresponds to that thing in the environment which the system is controlling. In a shower thermostat the input function generates a perceptual signal which corresponds to the temperature of the water comming out of the shower. The second element is a comparator which compares the perceptual signal with a reference signal. The output of the comparator is an error signal which is the difference between the reference and perceptual signals. For example in the thermostat if the reference level is 15°C and the actual temperature of the water comming out of the shower is 12°C the error signal will be -3°C. The third element of the control system is an output

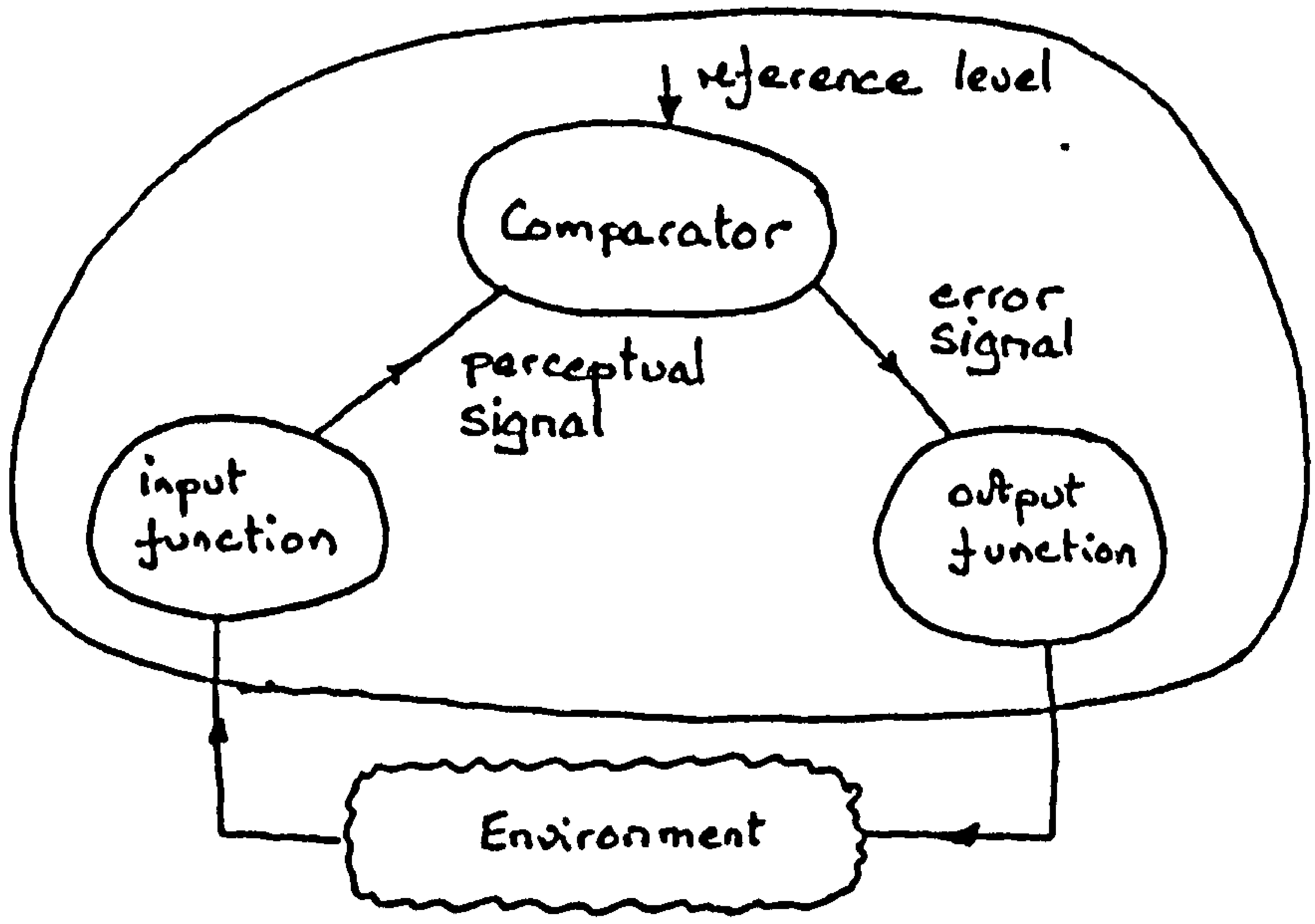

Figure 8.2 Elements of a unit within a control system

function which converts the error signal into an appropriate action. In the example of the shower thermostat, it could be set up so that a negative error signal would cause the output function to increase the proportion of water taken from the hot supply.

Memory

A fourth element can be added to the simple unit within the control system. This is memory. The action of memory is to record conditions which occur in the environment and the actions which led to zero error signals. The idea is that after a zero error condition has been achieved once it can be repeated. Figure 8.3 illustrates a possible location for memory within a unit of a control system.
Memories are stored from the in coming signals (via the "storage" link). In this configuration the action of the output function is to send an address signal to the memory which then produces a reference signal (or signals) for units at lower levels within the system tò act on.

By introducing two switches into the information flows with units at lowerlevels it is possible for the unit to act in any of four different modes. These are control, passive observation, automatic and imagination modes and are illustrated in Figure 8.4.
Each unit within a hierarchy can behave predominantly in one of these four

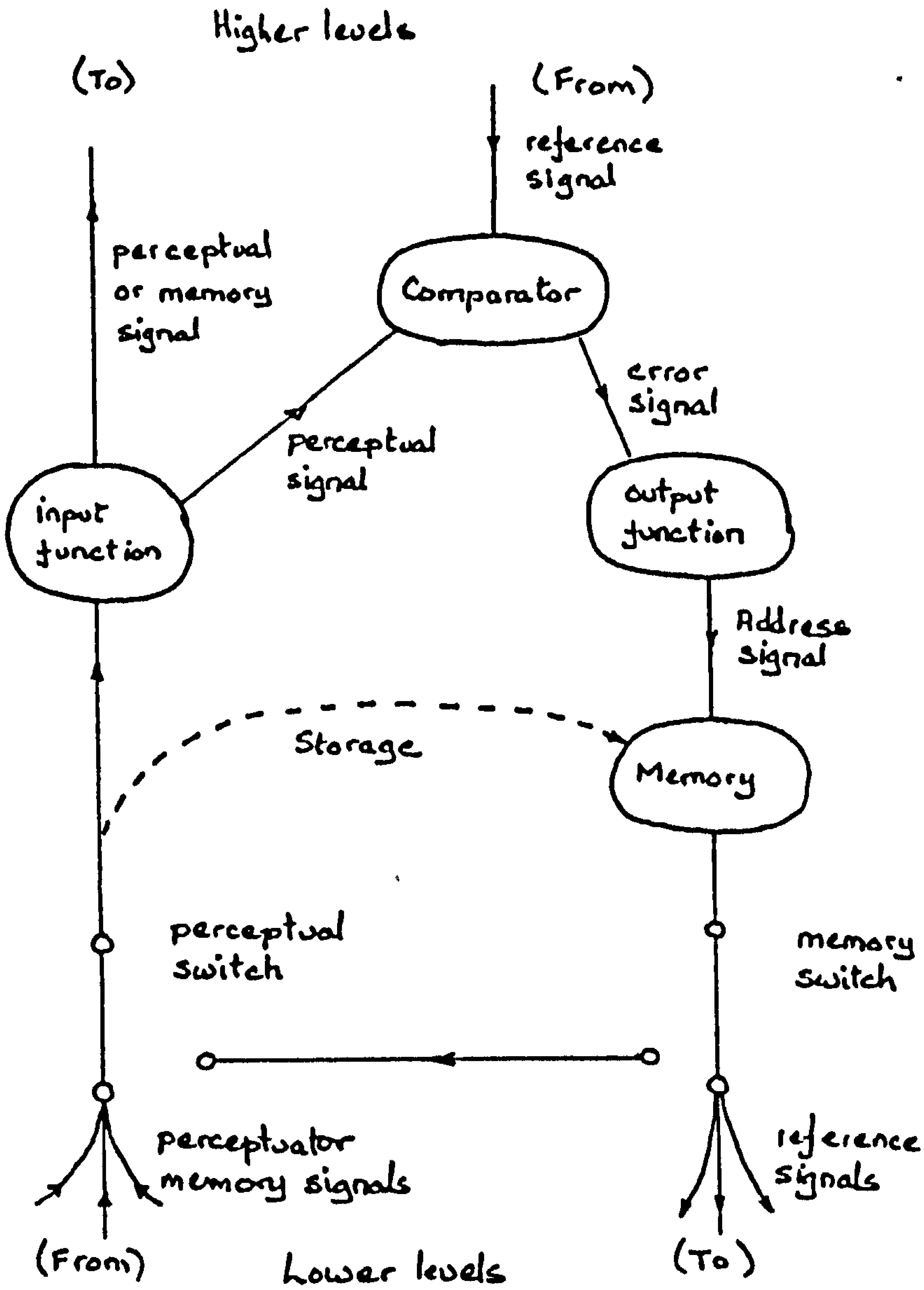

Figure 8.3 Memory within a control system

basic modes.

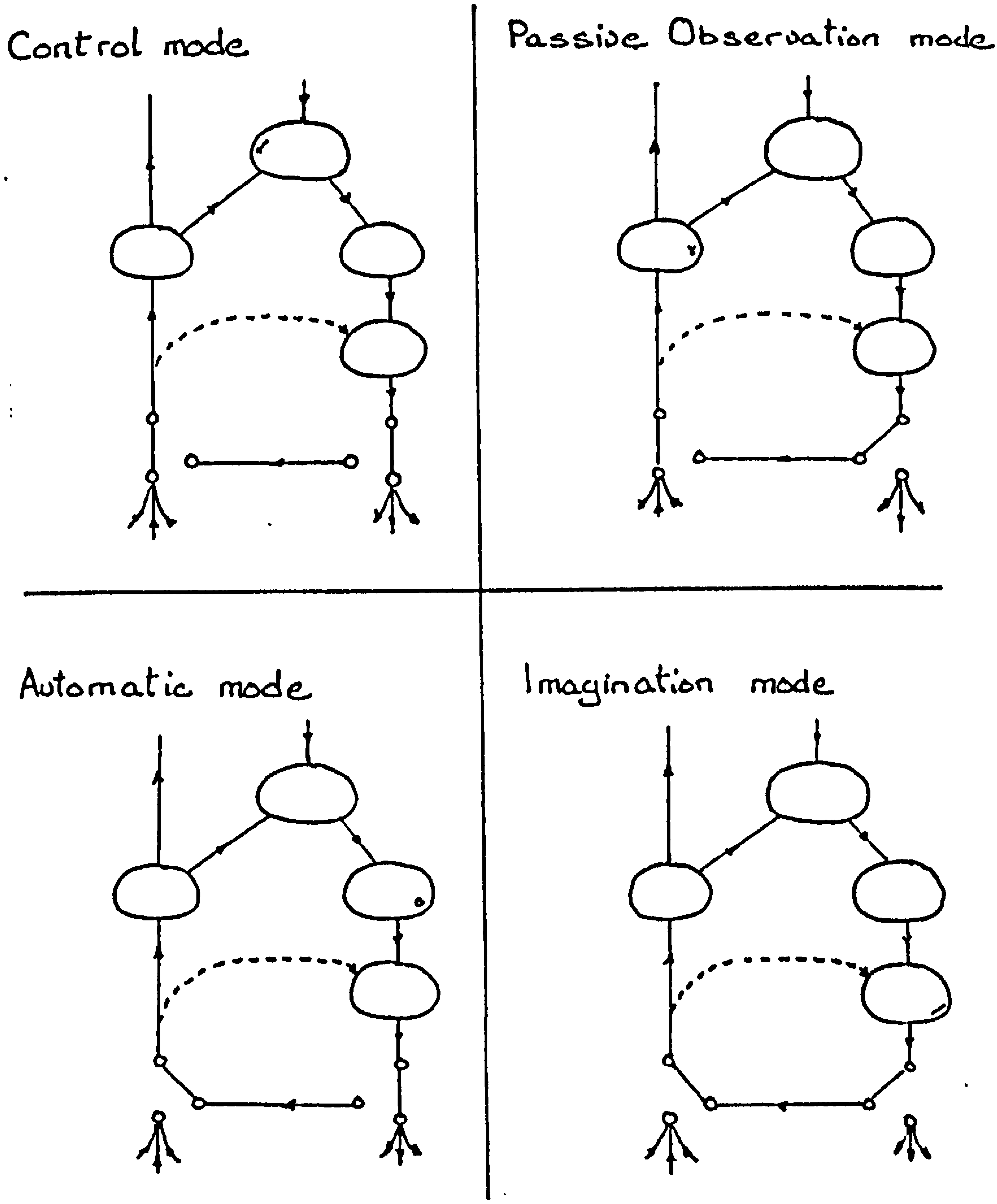

Figure 8.4 Modes in which a level of a control system can operate

Levels of control and modes of operation

Within any control system there will usually be units at several levels. Each unit within the system will predominantly be in one or other of the four modes. As an example I will discuss a model of a Local Planning Authority. This model is illustrated in Figure 8.5.

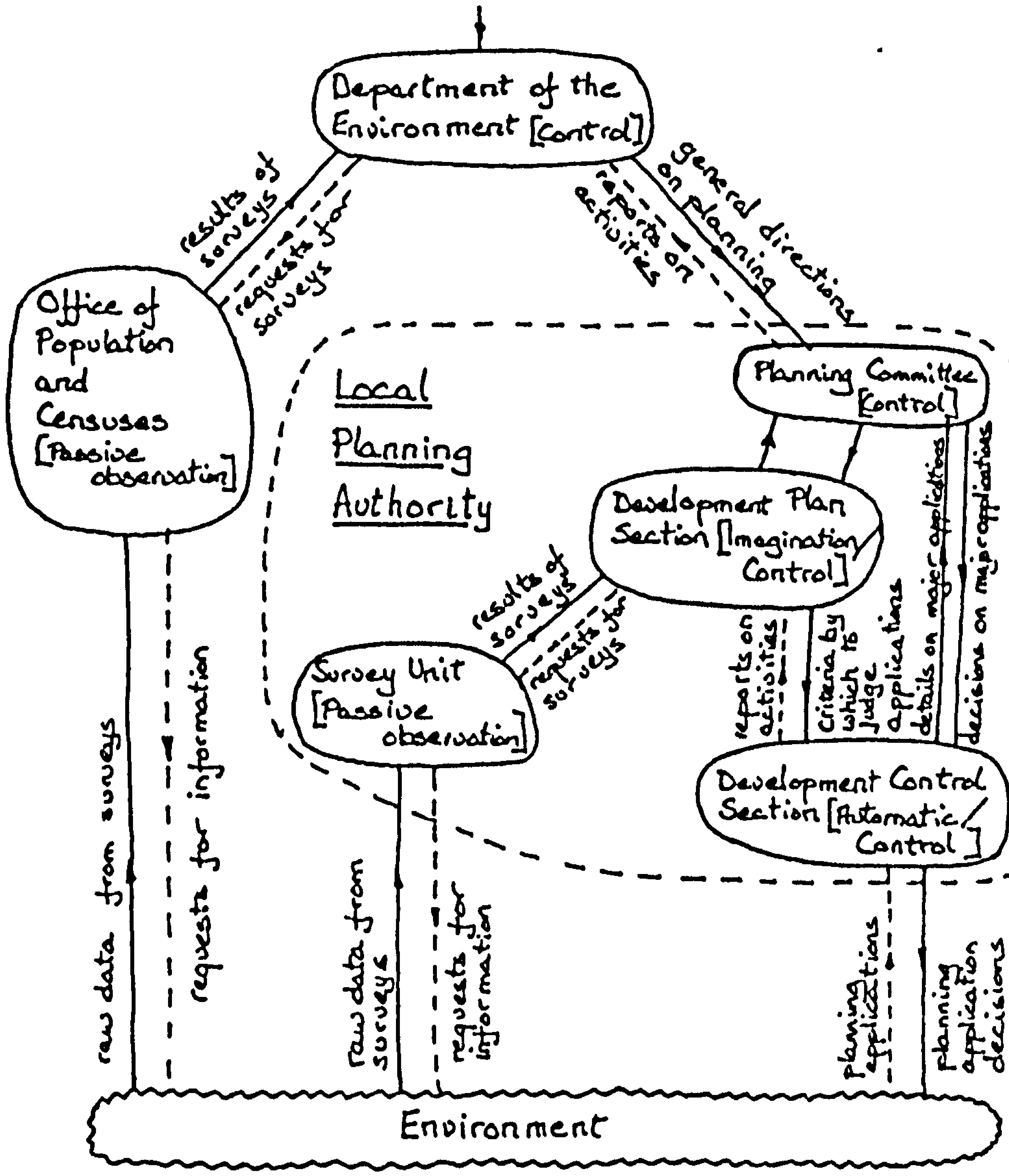

Figure 8.5 Model of Local Planning Authority

In this example the main controlling units are the Department of the Environment and the Planning Committee. Most of the information on what is happening in the environment comes from the Office of Population and Surveys and the Local Authority's Survey Unit. Both of these operate predomenantly in passive observation mode. The Development Plan Section will work mainly in imagination mode but will also on occasion operate in control mode. Finally the Development Control section will mainly operate in automatic mode. That is within specified criteria a planning officer can decide upon planning applications without reference to higher levels within the hierarchy. Although each unit may predominantly operate in one

mode, it will also operate in others. For example the survey unit will also operate in automatic mode when it conducts surveys. However the effect which conducting surveys has upon the environment is small.
However on occasion (for major applications) the Development Control Section will operate in control mode.

Rates of response

One of the important things about control systems is that to be effective the reference signal at any level must change at a slower rate than that at which the perceptual signal can be altered by the control system.

As an example consider using the previously described shower thermostat. There are now two levels of control. These are the person taking the shower who has as a reference level a criterion of "comfort" and the thermostat which has as a reference level the output water temperature. Within this system there is a time lag due to the time it takes water to pass from the thermostat and emerge from the shower. Due to this time lag, the fastest that the person taking the shower can change the reference level of the thermostat and be certain that they have changed it to their required level, is once every time lag period. If they alter the thermostat setting at a faster rate than this they will not know if they have achieved their required temperatures for each setting of the thermostat.

This has an important implication for a control system in which all levels are in effective control of the lower levels. The lowest level will have the fastest response rate and the highest level will change the reference level for the next level at the slowest rate.

Another aspect of control systems is that individual levels within a hierarchy can oscillate about their reference levels. The frequency of oscillation is closely related to the response rate of the next lower level within the hierarchy. Oscillation can occur when the response rate of the control system is near to that of the factor which is being controlled. For example, if the person taking the shower takes the same amount of time to decide that the water is too hot or cold, as it takes for the water to pass from the thermostat to shower nozzel, then ocillation may occur. This will happen if the person over corrects the thermostat setting each time the water is too hot or cold.

8.3 Why Plan?

Resolution of problems

I will use Faludi's (1973a, p82) definition of "a problem as a state of tension between the ends perused by a subject and his image of the environment." Planning is generally concerned with the development of programmes which when effected will alter the environment and so reduce the state of tension between ends and image. In this section I will look at some of the common causes of this state of tension.

Alternative futures

One of the sources of tension can be due to the perception of alternative futures from which the subject has at least a limited choice. In this case the subject will be able to evaluate the future images against his goals and so decide that one or more futures are preferable to the others. The perception that some futures are better than others can lead to planning to ensure that the "better futures" come about.

Desire for efficiency

A further cause of tension can be due to a desire for efficiency [2] or non arbitrary-ness [3]. There may be more than one way, or feasible programme, to achieve a goal. Some of these various programmes will be easier to implement than others. My perception is that there is a general

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[2] By efficiency I mean the best use of resources. That is the minimum expenditure of resources to achieve a given end. A process is efficient if it acheives its end with a minimum use of resources.

[3] An arbitrary act is one which is performed for no reason, so a non-arbitrary act is one which is performed for a reason, it is a purposive act.

tendency to desire an easier over a more difficult course of action to achieve a goal.

Conflicting goals

A third general source of tension is the existence of multiple goals. In many cases the attainment of one goal will conflict with the attainment of another. In this case a programme to achieve one goal will lead to an image of the future which is incompatible or conflicts with another goal.

Long term planning

There are several factors which lead to long term [4] planning. The first of these factors are long lead times, both internal and external. For example in the Electricity supply industry the planning of a new station from the point at which its necessity is perceived to the point at which it is ordered can take several years (internal time-lag) and its construction can take a further five to ten years (external time-lag).

Another factor which leads to long term planning is the long lifetime of infrastructure. For example there is usually a desire that a new road with a notional life of perhaps 30 years should represent an optimal use of resources not in its first year of use but over its whole life.

Other factors which can lead to long term planning are the perception of such things as finite resources and "limits to growth".

8.4 Areas in which Planning is Performed

There are many areas in which planning takes place from the individual level upwards. However the activity is more formally developed in some organisations than others and it is these developed forms of planning which I shall describe.

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[4] I take long term to be more than five to ten years.

Town planning

The process of town planning is highly developed in the UK, being covered by statutory requirements. It originated in 19th century public health legislation. Its basic components are a responsibility of local authorities to produce structure and local plans, and the control of development by planning permission.

The application of the above model to town planning by a local authority is illustrated in Figure 8.5.

Transport planning

Two areas in which transport planning occurs will be looked at. The first is at the conurbation level. One of the first conurbation wide transport planning exercises was conducted in Chicago in the early 1950's. Following the Buchanan Report, Traffic in Towns (Buchanan 1963), there were several such exercises in the 1960's in the UK. Examples were those conducted for Glasgow (Tippets et al 1967) and London (Greater London Council 1966). These large scale exercises have more recently given way to Transport Policies and Programmes which are prepared annually by local authorities as part of their bid for the Transport Supplementary Block Grant.

A second example of transport planning is that of motorways. In this case the planning is conducted at the national level by the Department of Transport as illustrated in Figure 8.6.
However this illustration is incomplete since the information flowing into the Department of Transport comes from more sources than the DVLC.

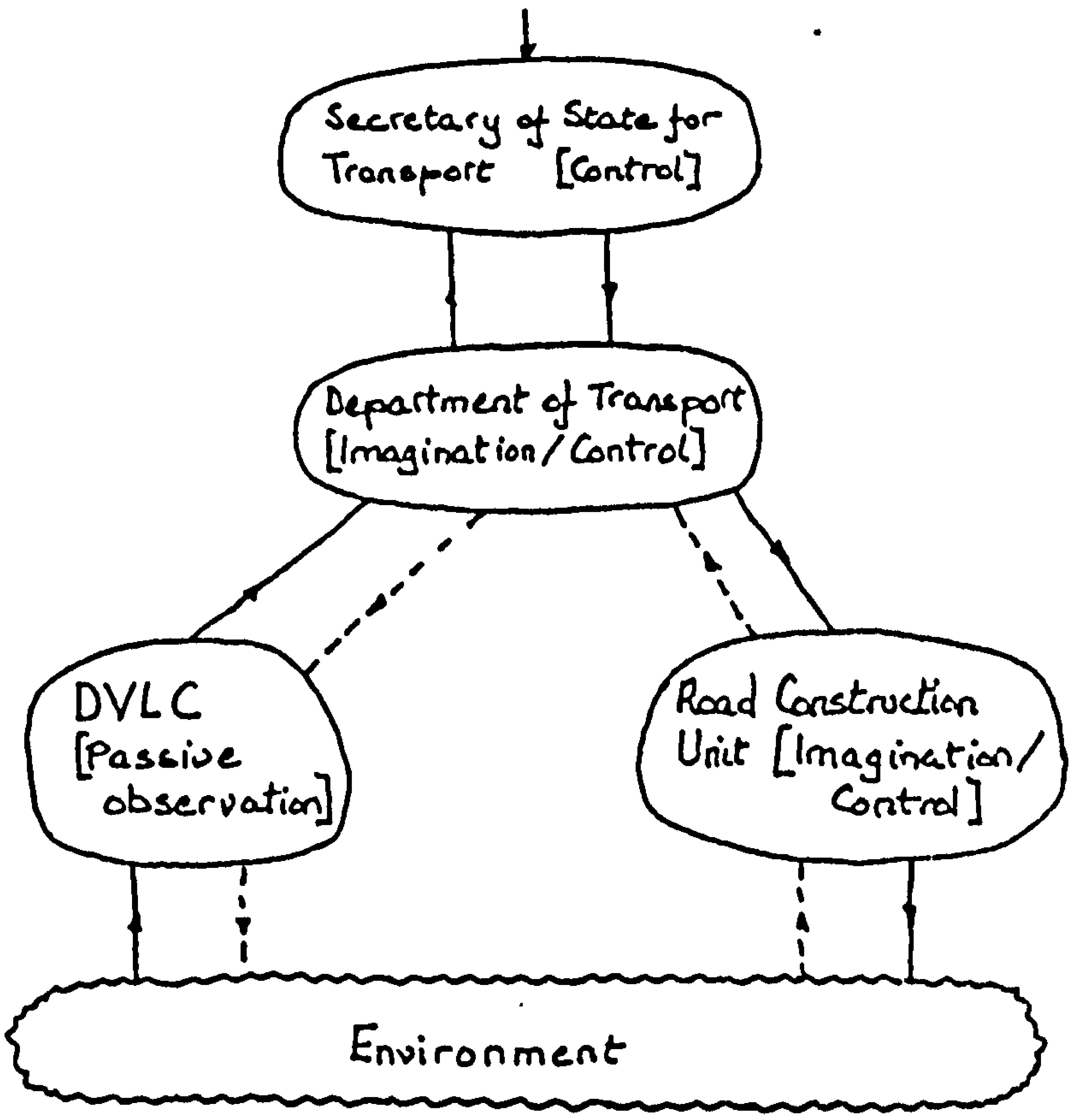

Figure 8.6 Model of Motorway Planning

Government planning

Most government functions involve planning and, apart from the previously mentioned transport and town planning, examples can be found in the fields of: the economy, education, housing, health, and defence.

Economic planning is taken as an illustration and is shown in figure 8.7.
In this case the major source of information flowing into the Treasury is received from the several branches of the Government Statistical Service. For example it comes from information on wages and unemployment collected by the Department of Trade and upon information on the balance of payments collected by the Central Statistical Office. Possible programmes are developed within the Treasury (operating in imagination mode), and selection of programmes is made by the Cabinet. One way in which economic programmes can be effected is through taxation. This is illustrated by

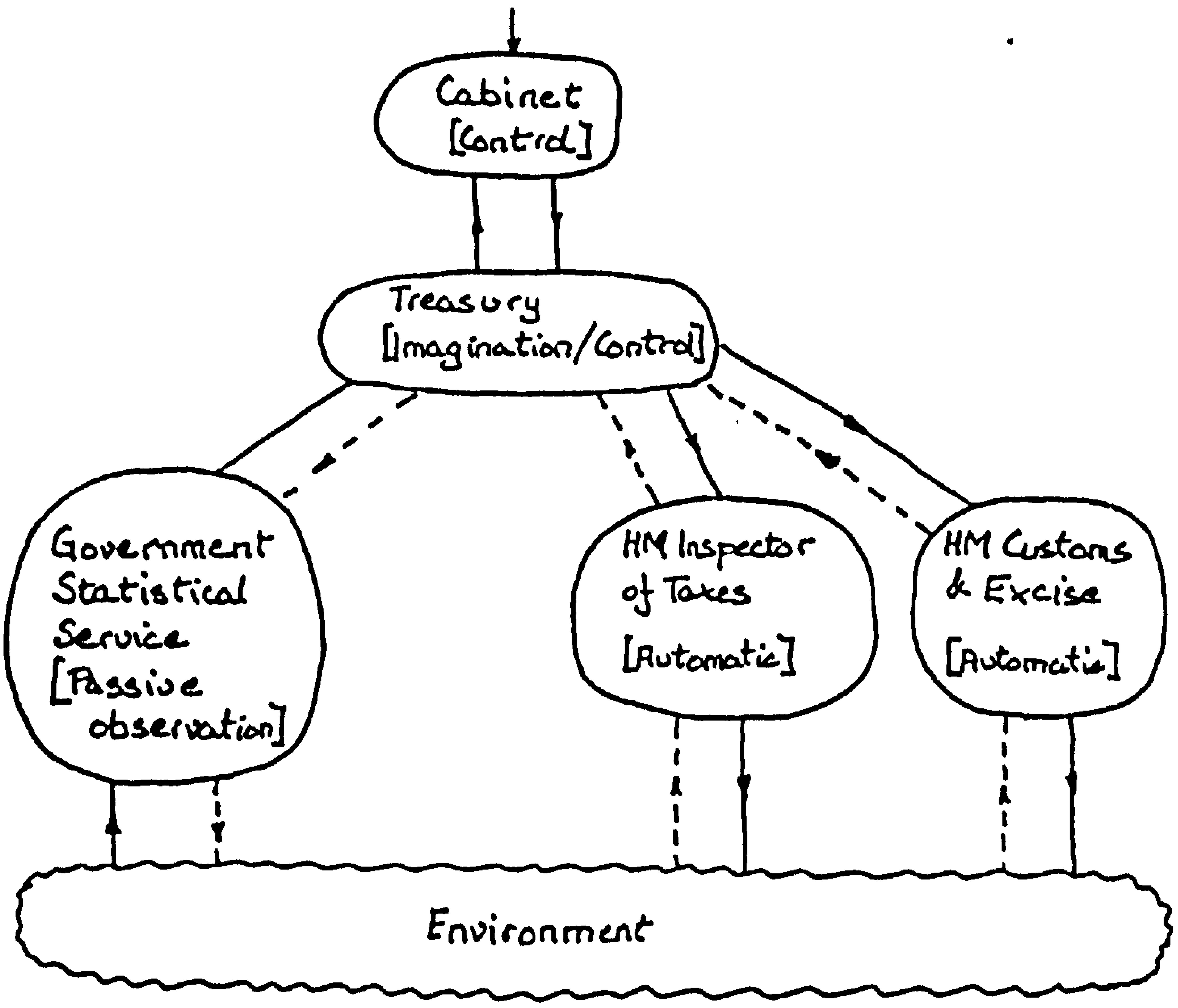

Figure 8.7 Model of Economic Planning

showing HM Customs and Excise and HM Inspector of Taxes. However this picture is incomplete since the Treasury also has other controls such as of government spending.

Business

In business planning can range from that of the long term future of a large corporation to that of a sales drive or a days production in a factory.

8.5 Description of the Planning Process

In "Planning Theory" Faludi (1973a) categorises descriptions of the planning process in three ways. These categories can be delineated by descriptions of processes which lie at the ends of the continua. The three continua are:

Blueprint to Process mode of planning
Rational-comprehensive to Disjointed-incrémentalist
and Goals to Means as a focus for planning.

In this section each continuum is described with some illustrations of the corresponding processes.

<u>Blueprint or Process mode of planning</u>

The "blue print mode of planning is . . . an approach whereby a planning agency operates a programme thought to attain its objectives with certainty" (Faludi 1973a, p131). An example of blueprint planning is the design of a civil engineering project such as a large bridge. In this case it is known that the goal, of providing a crossing over a river at a given point, will be met by execution of a given programme, the building of the bridge.

"The process mode of planning, on the other hand, is an approach whereby programmes are adapted during their implementation as and when incoming information requires such changes" (Faludi 1973a, p132).

Situations where there are firm images and complete control over the environment will lead to Blueprint planning whereas uncertain images and incomplete control will tend to lead to the process approach. There are however constraints imposed by time-lags. In Blueprint planning the complexity of preparing a programme will often lead to long internal time-lags and the size or complexity of the programme will often lead to long periods for implementation (external time-lag). An example of both these time-lags is provided by power station construction. In process planning there needs to be a reasonably rapid feed back from implementation of a programme and the formation of a new image of the resultant changes in the environment. This means that for process planning the time-lags must be short. For example process planning would be very difficult for the planning of electricity generating capacity (within the current structure of the UK industry) because of the previously mentioned long lead times in power station design and construction.

Rational-comprehensive or Disjointed-incrementalist

There has been a long standing dispute between those who think the aim of planning should be "the synoptic ideal" and those who think that not only is the synoptic ideal unobtainable but that it is undesirable. The synoptic ideal can be summarised as:

knowledge of unambiguous goals
a comprehensive image
identification of all relevant programmes
evaluation of the consequences of all programmes
selection of the programme which best achieves the goals.

However criticisms of the ideal have been made. These are that the ideal is:

incompatible with man's limited capacities
not suited to incomplete information
unrelated to the costliness of decision making
unable to cope with value system failures
not adapted to fact and value being closely related
not adapted to most systems being open rather than closed
not adapted to a sequential approach to problems
not adapted to the forms in which problems emerge.

These criticisms led Dahl and Lindblom (1953) to put forward a disjointed-incrementalist approach to planning as an ideal for which planning should aim.

Faludi (1973a, p155) gives the following definitions

> "The rational-comprehensive mode of planning is . . . that approach whereby the programmes put forward for evaluation cover the available action space and where the action space has itself been derived from an exhaustive definition of the problem to be solved."
>
> and
>
> the disjointed-incrementalist mode of planning is "where the programmes considered by any one Planning agency are limited to a few which deliberately do not exhaust the available action space, and where that action space is itself ill-defined."

Despite the difference between these two approaches there is in both a commitment to rationality. For example, "to ask why one values rational action is to demand an almost redundant answer . . . For by definition the more rational, efficient, and economical action leads to more net goal achievement." Dahl and Lindblom (1953, p40) continue: ". . . a commitment to rationality as a goal should not be taken as a commitment to an emotionally thin, desiccated, calculated, and excessively cerebral existence . . . The most rational act is not necessarily the most carefully calculated one."

Dahl and Lindblom (1953, p38) give the following definition of rationality. "An action is rational to the extent that it is 'correctly' designed to maximize goal achievement, given the goal in question and the real world as it exists. Given more than one goal (the usual human situation), an action is rational to the extent that it is correctly designed to maximize net goal achievement. When several actions are required to attain goals, rationality requires coordination; that is, the actions must be scheduled and dovetailed so that net goal achievement is not diminished by avoidable conflicts among the actions."

They also say "The more rational action is also the more efficient action. The two terms can be used interchangeably. Stripped of prejudicial inferences, efficiency is the ratio between valued input and valued output." (Dahl and Lindblom 1953, p53)

Cross (1975, p10) gives a summary of Robinson's (1972a) description of "the now familiar and well established model of the rational planning process". (I have added emphasis for easy reference to my comments given below.)

> "(1) Identify the problem or problems to be solved, the needs to be met, the opportunities to be seized upon, and the goals of the community to be pursued, and translate the broad goals into measurable operational criteria;
>
> (2) Design alternative solutions or courses of action (plans, policies, programs) to solve the problems and/or fulfill the needs, opportunities, or goals, and predict the consequences and effectiveness of each alternative;
>
> (3) Compare and evaluate the alternatives with each other and with the predicted consequences of unplanned development, and choose, or help the decision-maker or decision making body to choose, that alternative whose probable consequences would be preferable;
>
> (4) Develope a plan of action for effectuating or implementing the alternative selected, including budgets, project schedules, regulatory measures, and the like;

(5) Maintain the plan on a current and up-to-date, basis, based on feedback and review of information to adjust steps 1 through 4 above."

I have the following comments to make on the above description of the rational planning process:

(a) In the first step the translation of goals into measurable criteria can be criteria which are either numeric or that one outcome is better/worse than another. In this case "measurable" will usually be numeric but need not be. In most cases of planning it appears to be so and I think that this is a mistake.

(b) In the second step "predict" could profitably be replaced by "forecast", since Cross seems to attach a much less definite meaning to the term than I do.

(c) The evaluation of alternatives is on the basis of the operational criteria. However the basis of evaluation is not mentioned. Evaluation needs values to be attached to the operational criteria, such as better or worse.

Cross (1975) summarises the five necessary conditions for Webber's (1968 & 1969) 'Idea of Planning' as:

"1. The statement of goals, objectives and targets for each sub-system under consideration.

2. Continuing qualitative and quantitative forecasting of the future course of events which is outside control.

3. 'Continuing forecasting of the likely chains of consequences within and especially among sub-systems, that would result from each of a number of alternatively hypothesized sets of planned actions'.

4. Investment costs and welfare pay offs for each forecast alternative are compared with objectives. If there is good agreement a strategy is devised composed of programmes of action to target dates. These in turn are examined to find their pay off of welfare against investment costs and then expressed as budget items.

5. Continual monitoring of the performance of the system being planned to provide information on actual outcomes to correct errors in forecasting and to give early warning of dangers and opportunities.

Such a system of planning is, in Webber's words:- 'essentially an economising approach to the future, constantly appraising trade-offs among alternative investment strategies in search of desired welfare returns'." (Cross 1975, p71)

Goals or Means as a focus for planning

The third way in which planning can be classified is by whether or not the goals of a planning agency are questioned as part of the planning process. Faludi (1973a, p175) draws a distinction between normative planning, in which "goals and ojectives defining, inter alia, the limits of the action space of a planning agency, are themselves the objects of rational choice, and [in which] that choice is reviewed as and when the need arises", and functional planning in which "the goals and objectives defining, inter alia, the limits of the action space are not questioned."

8.6 Why Planning needs Forecasts

Some of the reasons why planning needs forecasts are given below.

> "One of the principal characteristics of planning is its orientation to the future. Davidoff and Reiner (1962) write:- 'Time is a valued and depletable resource consumed in effecting any end. Planning, an end-directed process, is therefore future oriented. Each of the ultimate objectives of planning implies a need in the present for information about the future. Estimates of future states are also important for what they imply for present behaviour; thus, points are identified where control is required if ends are to be achieved. Moreover, planning involves assigning costs to deferred goal satisfaction and to losses arising from proposed actions'" (Cross 1975, p12).

> "If we are to postulate future actions, clearly we must be able to form some image of what the future is going to be like, and ordinarily we act in the anticipation that the future will be like the past has been, or largely so, or else we anticipate some change which is likely to occur and modify our image of the future to accord with this change" (Chadwick 1978, p155).

> "It is possible to forecast without planning but it is not possible to plan without forecasting, even if the forecast and the plan are closely identified as a future end state based on present values. This intimate connection between forecasting and planning makes it difficult to write about forecasting in . . . planning as a separate aspect of the larger whole. Because planning is necessarily future oriented forecasting is a recurrent theme in most aspects of the subject. An attempt to write about forecasting without placing it

> in the wider context of the planning process would therefore not only tend to be rather sterile but would tend to emphasize specific technical problems rather than an overview of principles and method. Nevertheless because forecasting in order to plan is essentially a practical activity some consideration of the nature of forecasting problems and methods in an operational situation is needed. A balance between these different requirements is necessary" Cross (1975, p1).

In the terms of the framework developed in section 8.2 any unit in a control system which is working in imagination mode may make or use forecasts. It will need to make forecasts if it "thinks" that the environemt will change by the time that actions take effect.

> "Planning is connected not only with 'objective' or positive forecasting of what is likely to happen if such and such courses of action are pursued but normative forecasting of what should happen . . . In . . . a general planning process, the identification of problems and the choice of goals etc. is essentially normative forecasting" (Cross 1975, p12).

8.7 Summary

In this chapter I have given a framework within which planning processes can be considered. Further references to this framework will be made in the next chapter. I gave examples of planning in different fields and also various ways in which planning can be classified and described. Finally I outlined the ways in which planning leads to forecasting.

9. CONCLUSIONS AND FURTHER WORK

In this final chapter I shall give my views on the place of forecasting within the planning process, why forecasts are seen as being necessary, how they can be avoided and some insights I have gained into welfare economics. I shall end the chapter with some areas in which I think further work would be fruitful.

9.1 Planning and Forecasting

Two different views of the role of forecasting within the planning process can be held. In one view forecasting plays a central role by providing a background against which the formulation of programmes of action can be planned. It is this view which was put forward in the previous chapter. In the other view forecasting can be seen as coming after the point at which the general outlines of programmes of action have been decided upon. Forecasts are then used to fill in the details of these programmes, for example by helping to decide what is "economic", and to defend them in public. In their own ways both views can provide insights into the planning process.

My views of forecasting, as given in Chapter 7, have implications for the planning process. At the political or goal setting level the acknowledgement is required that forecasts are subjective, and at the practical or programme formulation level ways of avoiding forecasts or overcoming their deficiencies need to be found.

It appears that there is, at present, a very widely held belief by planning practitioners that forecasts form a value free input to the planning process. In a critique of traffic forecasts, and road transport planning, Adams (1980) points to the following circularity. In the absence of a clear policy, traffic forecasts are based upon the hypothetical government policy that the greater use of cars is desirable and upon an assumption that roads will be built to accommodate them. The resultant forecasts are then used to say that roads are necessary to accommodate the forecast increase in traffic. This is a good example of a forecast being used as a goal setting avoidance technique.

In "Social Forecasting: Predicting the Future or Making History?" Miles and Irvine (1979) have the following to say about the use of forecasting. "Adequate analysis of the conditions needed to establish a better future is part of the process of creating that future. Methods of assessing the contributions that alternative actions . . . might make to realising social goals are necessary, and some of the existing forecasting techniques may well be applicable - if it were absolutely clear that the use of these methods was itself part of the process of making history. Forecasting practices which treat people as doing no more than reacting passively to changes beyond their control need to be replaced by people assuming responsibility for democratically formulating and planning social goals."

The implication is that forecasting is not a value free objective activity. However the adoption of Mile's and Irvine's suggestion would require new structures or modes of organisation within society.

At the practical level it is often acknowledged that forecasts cannot be made, however it is usually then claimed that something must be done and this is usually seen as being to make and use a forecast anyway. My view is that the solution to the problem is not to be found in improved forecasting technique but rather in ways of avoiding or reducing the need for forecasts. I shall say more about this below.

9.2 Why forecast?

In the previous chapter I outlined some of the reasons why forecasts are required within the planning process. In the terms of the human mind analogy forecasts fulfill the requirement for a future image of the environment against which actions are taken. The length of time over which a future image is required is determined by the time lags in the system between an action being initiated and the perception of changes in the environment.

Under the view that forecasting comes after the basics of an action programme have been decided, forecasts are necessary to defend the actions decided upon and to determine the details of the programme. For example forecasts of increasing road traffic have been used in much this way both to justify motorway schemes and to make decisions as to which motorways to build. Another example is the use of energy forecasts to defend the current nuclear power building programme.

9.3 Ways to avoid forecasts

There are several ways in which the necessity for making longterm forecasts can or could be avoided. These include having shorter lead times, letting more functions within the planning organisation be carried out in automatic mode, introducing more feedback and accepting less "efficiency" within the system being planned. These four approaches can be directly related to the human mind analogy of planning presented in the previous chapter. Shorter lead times will principally have an impact upon the types of programmes which are developed and accepting less "efficiency" will alter the goals the system is working towards. In practice the distinction between more feedback and shorter lead times is rather blured.

One of the problems inherent in many of todays large systems are long lags between an action being initiated and a result being perceived in the environment. There would seem to be several advantages to be gained from reducing these lead times in planning systems.

An example of this would be a change from the use of large generating sets in the electricity system to the use of smaller sets. These advantages would stem from the shorter length of time between ordering and installation. This would be beneficial because the shorter term forecasts required are more likely to be "accurate", and recovery from any errors made due to poor forecasts would be quicker.

Another way of avoiding forecasts is to move towards self governing systems and away from the external control of systems. This could be achieved by letting more units within the control system operate in automatic mode (automatic programmes). It would probably require the introduction of some of the other measures I have mentioned.

For example the introduction of a capacity tax on the price of electrical appliances (as proposed by the Energy Research Group, 1976) could be used to substantially reduce the necessity for making electricity demand forecasts. However this would need to be in conjunction with a move towards the construction of electricity generating plant which has shorter construction lead times so that the plant building programme could respond quickly to changes in the capacity tax levied.

I would like to think that the human mind analogy of the planning process could be stretched to the point where automatic programmes could develop of their own accord once awareness was focused on the issue at hand. Such methods of developing automatic programmes would be similar to the methods of learning propounded within the "Inner Game" (Gallwey 1974, Gallwey and Kriegel 1977).

Many instances of self regulating systems can be found in nature. Two of their main characteristics are diversity and redundancy. With these, such systems are able to cope with large changes in their environment without the system collapsing. However such characteristics are currently not deemed to be desirable in the so called advanced societies because it is not "economic". For a given expenditure of resources more can be achieved if there is less diversity and redundancy. However the resultant systems tend to be much less stable to unexpected events. It is in such systems that forecasts of the changing environment are perceived as being necessary.

In conventional economic terms what I am suggesting is that a higher value or price should be placed upon system stability than is done at present. The direct use of a price would be very difficult to achieve in practice since there is no market for system stability and its price would be difficult to determine. However economics is not the final arbiter of what is done in society. There tend to be several overriding arguments to do with "insurance" and "national security". For example the army is uneconomic.

My views on ways to avoid forecasts (as above) are to some extent held by some others, for example:

> "The management of complex organisations is now recognised to be a continuous steering process, and hence planning to be concerned with the definition of objectives, i.e. what is to be achieved, the identification and choice of a route to that achievement and the control of progress along it. Likewise, those concerned with governing and managing now accept that uncertainty is the corollary of complexity, and have threfore come to interperet anticipation in a somewhat different way. The planning process can explore alternative futures. But prediction and control of the future have come to be less important relative to anticipation of continual surprise and the creation of an organisation capable of responding creatively to changing situations". (Center for Environmental Studies 1973).

Commenting on this Cross (1975) says "In such an approach to the planning process forecasting is much less important because of the short time horizons and because more rapid problem perception and speed of response is substituted for it." However I don't believe that the general recognition that CES claims to exist does actually exist within many planning environments such as central government. Such recognition seems to be restricted to some academic circles.

9.4 Welfare economics

Welfare economics is concerned with equity and efficiency. I have previously found (Baker 1974) that it cannot satisfactorily cope with equity because of the impossibility of making objective interpersonal comparisons. There are several standard defences of ignoring equity such as that there are mechanisms within society that ensure that the distribution of income is socially acceptable. Using such arguments welfare economics has tended to concentrate almost exclusively on the efficiency or optimal distribution of resources aspect. This has been because it is perceived that it is possible to do this in an "objective" manner.

I have now come to the conclusion that this side of Welfare economics (the efficient allocation of resources) is equally built on shifting sands. The foundation for most work on the efficient allocation of resources is the Pareto optimum. However one of the principal preconditions for the attainmant of a Pareto optimum is perfect information and this can never be attained in the real world since there can be no perfect information about the future.

9.5 Further Work

There are several different areas in which I can see an opportunity for further work as a result of this thesis. Briefly these are into:

- Welfare economics;
- Forecasting methods;
- The extent to which forecasts are used as the input to other forecasts;
- How to avoid making forecasts;
- The use of my model of planning as a framework for analysis;
- Reformulation of my concerns about forecasting;
- The structure of language.

Welfare economics

As noted above (Section 9.4) I have now become aware that both areas of welfare economics (equity and efficiency) are built on shaky foundations. It is principally in the area of the concept of economic efficiency and the use of the Pareto Optimality criteria that I think fruitful work could be done. On Pareto optimality the main thing which needs to be investigated are the consequences of the non-applicability of the preconditions for the attainment of the optimum allocation of resources in the real world.

In particular I have concluded that objective forecasts are not possible and so it is not possible to have perfect information about the future.

As an aside it is interesting to consider the age old paradox of free will and pre-destination. In the following plan and planning could equally well be replaced by the optimal allocation of resources.

If free will exists it is not possible to forecast,
and so it is not possible to plan.

If predestination exists it is possible to forecast,
but planning is futile.

So, depending on whether free will exists or not,
planning is either futile or not possible.

Forecasting methods

Notwithstanding the conclusion that I have come to that objective forecasting is not possible and has no place in the planning process, and also that forecasting models are of their nature prone to error, I do see a need for more work on forecasting methods. However any such work should start from the acknowledgement that objective forecasting is not possible.

A large area in which further work could be done on forecasting methods is in gaining greater understanding of the ways in which the systems being forecast work. For example in the case of freight transport the first step might be to construct time series of volume of production, movement ratios and average length of haul for all freight broken down by commodity and mode as outlined in Chapter 1. This could then be followed by an examination of the underlying causes for the trends in these time series.

Circularity of inputs

Of the three sources of projected values for input to forecasting models only trend projection and goals are autonomous inputs to the totality of the forecasting process. As shown in Chapter 5 (Figure 5.5) other forecasts are not autonomous. For example most forecasts of transport demand and of energy demand use population forecasts as one of their inputs. In their turn population forecasts use forecasts of economic growth, and so on.

It would be very interesting to make a collection of forecasts and trace the flow of forecast outputs used as inputs in other forecasting exercises. At one level this would entail identifying numbers input to a forecasting process which were explicitly acknowledged to come from another forecast. At a different and more difficult level it would entail identifying how individual forecasts and the general background of forecasts influenced the forecaster in making his judgements.

Avoidance of forecasts

Above I have put forward ways in which forecasting could either be avoided or its role could be reduced. However there are many details which will have to be worked out if these ideas are to be implemented. These include both detailed studies of individual cases and studies of the underlying principles.

In particular planning situations examination will have to be made of which of the suggested approaches or mix of approaches to the avoidance of forecasting are most appropriate and how they could be implemented.

A major study in its own right would be an examination of how diversity and redundancy as prerequisites for robustness in systems could be incorporated into economics or alternatively how economics could be replaced by a new discipline whose results could be used to help in policy formulation.

Another study which would help to determine the cost of uncertainty would be an empirical study of how the accuracy of past forecasts has been a function of the length of the forecast time period. I suspect that a reasonable hypothesis could be put forward that the "accuracy" of forecasts is an exponential function of the time period over which they are made.

Long lifetime products (such as roads and power stations) are planned for due to a desire that they be used "efficiently" over their lifetime. If forecasting problems mean that this is not possible perhaps the rules of the game (economics) should be rewritten so that the future is taken into account when decisions are made but that past signals (prices) are not carried into the future (by capital charges). This would mean that all capital formation would be out of current spending not future spending.

Another area in which work could be done would be examination of the feasibility of letting automatic programmes develop by the focusing of awareness in the appropriate place as mentioned in 9.3 above.

Uses of control system model of planning

Within the control system model of planning (as described in Chapter 8) it is possible to identify systems which will not work as intended. For example consider the directives (or control signals) from government to a nationalized industry, such as the electricity industry. If the directives change at the same or faster rate as that at which the industry can respond to these changes, then effectively the government will not have the control it desires over that industry. The effect will be that the industry will operate at some time average of the control signals. If the environment changes faster than the control system can respond, then the control system will not be in control.

The control system model could form a useful framework within which to analyse the way in which planning is conducted. It could be used to see if the system can actually respond to the control which is desired over it. It could also be used to devise ways in which control systems will work as desired.

Reformulation of the problem

I now realise that my concern is not with forecasts themselves, but with systems with long lead times between initiating action and reacting to perceived errors. If the lead times are similar to the reaction time of the control system then oscillation may occur about a desired reference level. If the lead times are also long the cause of such oscillations may not be apparent.

I think that it would be fruitful to examine how systems with such long lead times arose and how the lead times could be reduced rather than worry about the problems of making forecasts. One of the ways in which lead times could be reduced would be to reduce the number of levels in the hierarchy of control at which reference levels need to change.

Language structure

In writing this thesis I have had difficulty in giving "objective" definitions to the terms I have used. Often I have only had a vague idea of the meaning I wish certain words to convey, much like Gregory Bateson's "stuff" which is to be re-examined in more detail at a later date (Bateson 1975).

I have a feeling that the pressures to get a clear understanding of concepts before committing things to words (either verbal or written) may well have as much to do with the shortcommings of the language we use as with the desire or necessity to avoid woolly thinking. Maybe my perceived difficulty in attaining great clarity of thought is due more to the structure of the language I use to express my thoughts than the nature of clear thought.

These difficulties may be a product of the subject-verb-object structure of our language or its underlying metaphysics (of cause and effect). I think it would be well worthwhile examining the ways in which the structure of language structures and limits our thought processes. For example the necessity to distinguish something from everything else (i.e. to divide reality into separate parts) before it can be given a name gives rise to the concept of "objective" reality. That is something which exists independently of me. If the language structure did not lead to the "objective reality" concept then much of the confusion that I have been trying to address in this thesis about "objective" forecasting would not arise.

There may be some answers to this in Language Thought and Reality: selected writngs of Benjamin Lee Whorf (1956).

APPENDIX 1. SOURCES OF DATA ON FREIGHT TRANSPORT

A1.1 Introduction

In this appendix I will give the sources of data which I used for each of the figures and tables in Chapter 1 and the data which is available for further work. These are covered below, in sections A1.2 and A1.3 respectively.

Prior to about 1975 all sources of Freight Transport statistics used imperial units. However in this appendix only metric units are used. In general all imperial data was metricated before use.

The most general source of data for recent freight statistics is Transport Statistics GB (Department of Transport annual a) which gives data on many aspects of transport, generally for the previous 11 years. However it was first published in 1976 covering the years 1964 to 1974. Prior to its publication some of the data it contains was published in Highway Statistics (Department of the Environment annual). Another general source of data is the Annual Abstract of Statistics (Central Statistical Office annual a) which gives estimates of the tonnes of freight lifted per year and tonne-km moved per year by each mode of domestic surface transport (Road, Rail, Pipeline, Coastal shipping and Inland waterway).

Apart from these few general sources most freight transport statistics cover individual modes. Some of the exceptions to this are the details given in the Digest of UK Energy Statistics (Department of Energy annual) of coal tonnages lifted per year, and of oil tonnages lifted per year and tonne-km moved per year, by each mode.

The figures which would be required for further work, are the tonnes lifted per year and tonne-km moved per year by each mode, for as many commodities as possible. I will deal with the modes separately in the order Road, Rail, Coastal shipping, Inland waterway, Pipeline and Air.

I found no solution to the problem of some statistics covering GB whilst others cover Northern Ireland as well. In general the sections in A1.3 on each mode make no specific reference to this problem, nor is mention made of the details available in Department of Energy (annual) on coal and oil.

A1.2 Sources of Data used in Chapter 1

Figures 1.1 and 1.2

The tonnages of freight lifted per year and the tonne-km of freight moved per year by all modes were obtained from several years Annual Abstract of Statistics (Central Statistical Office annual a).

Figure 1.3

The average distances over which freight was moved were derived from the data used for Figures 1.1 and 1.2.

Figure 1.5

The production of coal per year was obtained from several years Digest of UK Energy Statistics (Department of Energy annual) and the remaining primary inputs and imports were obtained from Central Statistical Office (annual a). As noted in Chapter 1, subsequent to the analysis I found that the data given in Central Statistical Office (annual a) does not cover all imports.

Figure 1.6

The average number of moves was derived form the data used for Figures 1.1 and 1.5.

Figures 1.7 and 1.8

The commodity breakdown of tonne-km moved per year and of tonnes lifted per year in GB was based upon data given in Transport Statistics GB 1964-74 (Department of Transport annual). This gives details of the eight commodities moved and lifted by Road, Rail and Pipeline. The figures for the other modes were estimated such that the totals for all commodities agree with the data used for Figures 1.1 and 1.2.

Figure 1.9

The average distance over which freight was moved was derived from the data used for Figures 1.7 and 1.8.

Tables 1.1, 1.2 and 1.3 and Figure 1.10

The way in which the net volume of production of each commodity in 1968 was obtained is explained in Appendix 3. The corresponding figures for 1962 and 1974 were estimated on the basis of production figures for the 3 years given in Central Statistical Office (annual a).

The quantity of each commodity lifted in 1962 and 1974 were those used for Figure 1.8.

The quantities for 1968 were found by interpolating between the figures for 1962, 1967/68 and 1974 and then pro-rating the figures so that the total of all goods lifted was equal to that given in Central Statistical Office (annual a). This adjustment was of the order of 1%.

The average number of moves were derived from the previously mentioned two sets of figures.

Figures 1.11 and 1.12

Details of the supply, tonnage lifted and tonne-km of petroleum moved each year were obtained from Department of Energy (annual). The average number of moves and average length of move were then derived. (This time series is only available from 1965 to 1975).

A1.3 Sources of Data for Further Work

Road

The main sources of data on road freight transport are the sample surveys which were conducted in 1952 (Glover and Miller 1954), 1958 (Ministry of Transport and Civil Aviation 1959), (Glover 1960), 1962 (Ministry of Transport 1964 to 1966), 1967-8 (Department of the Environment 1971) and a continuing quarterly sample survey since 1970 for which reports are available covering 1970-2 (Department of the Environment 1974a) and for 1973 and subsequent years (Department of Transport annual b). From 1974 results from the continuing survey appear in Department of Transport (annual a). (Details of the commodity classifications used are given in Appendix 2).

From the results of the sample surveys estimates of the tonnes lifted and tonne-km moved for different commodities each year can be obtained or made. Those made on the basis of the earlier surveys would be very approximate.

Details on the size of road goods vehicles, the types of operators and the work performed are also contained in the reports on the sample surveys. These can be compared with the numbers of goods vehicle licences held and estimates of the distance travelled by goods vehicles. Highway Statistics (Department of the Environment annual) contains details of vehicle licences by vehicle type and size. Distances travelled can be obtained from the 50 point traffic census (Tanner and Scott 1962, Dunn 1962,3,4,5,6,7, Dunn and Sheppard 1968, and Dunn 1970,1,2,3,4) and monthly road traffic surveys, the results of which are published in Department of the Environment (annual) and Department of Transport (annual a). For years prior to the establishment of the 50 point census and monthly road traffic surveys, details of goods vehicle travel are contained in a paper by Scott and Tanner (1962). Using this supplementary data it would be possible to make interpolations between the road freight sample surveys to obtain estimates of the work done by road goods vehicles in other years. However at a detailed level of commodity breakdown such estimates would be very approximate.

Rail

The Annual Report and Accounts of the British Transport Commission (1948 to 1962) and of British Rail (annual) give details of tonnes lifted per year, tonne-km moved per year and the average length of haul for Merchandise; Minerals; Coal and Coke (1948-62) and Coal and Coke; Iron and Steel; Other (1963-present). Transport Statistics GB (Department of Transport annual a) gives the same figures but with a more comprehensive commodity breakdown, from 1964 onwards. Deakin and Seward (1969) give the tonne-km moved per year for various commodities carried in 1958 and 1962. These figures were provided by the British Railways Board. The tonnage of approximately the same commodities carried by rail in 1962 are given in Ministry of Transport (1964 to 1966). The results of a survey conducted by BR in 1964 were used by O'Sullivan (1972) though he did not publish the results of the survey.

One problem with the statistics compiled by British Rail is the inclusion or non-inclusion of free hauled traffic; that is freight such as ballast and rails which British Rail moves for its own purposes. To be comparable with road freight statistics which include the movement of material for the maintenance of roads, free hauled traffic on the railways should be included.

Central Statistical Office (annual a) contains the tonnages carried per year of eight commodities carried by rail in Northern Ireland for the years 1949 to 1965.

Coastal Shipping

The Digest of Port Statistics (National Ports Council annual) gives the tonnages of 40 commodities inwards and outward every year for each major port from 1967 onwards. However it does not give their respective origins or destinations. These must be known or estimated for the calculation of the total tonne-km moved per year by coastal shipping which appears in Central Statistical Office (annual a).

The Survey of Road Goods Transport 1962 (Ministry of Transport 1964 to 1966) gives details of the tonnes lifted and tonne-km moved (inland equivalent) for 7 commodities by Coastal Shipping.

Ford and Bound (1951) give details of how they constructed an origin and destination matrix for commodities in 1948. They also give the tonnages lifted, tonne-km moved and average length of haul for 15 commodities in the same year.

Elliott (1968) gives an indication of the tonnages of coal delivered to different ports from the Tyne in 1937 and 1954. The work of Ford and Bound (1951) indicated that coal was the major commodity moved from the Tyne in 1948.

Failing all else it would be possible to construct a linear programming solution to the origin and destination problem posed by the inward and outward figures for the 40 commodities from and to each port contained in National Ports Council (annual). This would give a minimum value for the tonne-km carried per year for each commodity. However a problem which would first have to be overcome is that the tonnages of each commodity inwards and outwards at all ports do not balance. This is because "returns are received form the main, but not from all, the port authorities in Great Britain, and the figures do not cover the ports of Northern Ireland, the Isle of Man and the Channel Islands" (National Ports Council annual).

Inland waterways

The Annual Report and Accounts of the British Transport Commision (1948 to 1962) and of the British Waterways Board (annual) give details of the tonnes lifted per year and tonne-km moved per year of coal, coke and patent fuel; liquids in bulk and general merchandise on British Waterways Board canals. However in 1974 there were some 1560 km of commercial waterways of which only 550 km were owned by BWB. Baldwin (1977) has estimated that 380 and 350 million tonne-km were moved on inland waterways in 1973 and 1974 respectively. This is in contrast to the 100 million tonne-km for both years, shown in Central Statistical Office (annual a) which is equal to that moved by BWB only, and the 490 and 400 million tonne-km moved respectively for petroleum alone, as shown in Department of Energy (annual).

One of the problems which would have to be overcome, to prevent double counting, is the exact distinction between coastal and inland shipping. Another problem would be how to estimate carryings on non BWB canals for years other than 1973 and 1974. Finally it would be very difficult to obtain a detailed breakdown by commodity beyond the three commodities used in BTC and BWB Report and Accounts.

Pipeline

Central Statistical Office (annual a) gives the tonnes lifted per year and tonne-km moved per year by pipeline from 1953 onwards and Department of Energy (annual) gives these plus the average length of haul by pipeline from 1965 to 1975. Only crude and processed oils are considered to be carried by pipeline.

Air

Details of the tonnes lifted per year and tonne-km moved per year by air since 1949 are contained in Central Statistical Office (annual a), but no commodity breakdown is available. However the quantities of freight moved by air are negligible compared to other modes, so this lack of commodity detail probably does not matter. For example in 1968 only 0.09 million tonnes and 0.03 thousand million tonne-km were carried by air with totals of 1980 and 130 respectively by all other modes of transport.

A1.4 Commodity Classification

One of the major problems in assembling the data would be to obtain consistent commodity groups between the different modes of transport as each uses its own classification systems. The only method found would be to aggregate the data into a few commodity classifications. Details of the Commodity classifications used by each mode of freight transport and their relationship to each other are given in Appendix 2.

APPENDIX 2. COMMODITY CLASSIFICATIONS USED FOR FREIGHT STATISTICS

Different commodity classification systems are used for each mode of freight transport. Those used for the road goods surveys are based upon the Commodity Classification for Transport Statistics in Europe (CSTE, United Nation, Economic Commission for Europe 1968). The National Ports Council (NPC) code used for the port statistics is based upon the Standard International Trade Classification (Revised) (SITC(R), United Nations 1961).

The relationship between the road goods survey classifications and the CSTE is given in The Transport of Goods by Road in Great Britain 1973 (Department of the Environment 1975d). That between the NPC code and the SITC(R) is given in the Digest of Port Statistics (National Ports Council annual). The Commodity Classification for Transport Statistics in Europe (CSTE) (United Nations, Economic Commission for Europe 1968) gives the relationship between the CSTE and the SITC(R).

APPENDIX 3. NET PHYSICAL VOLUME OF PRODUCTION

A3.1 Introduction

As explained in Chapter 1, statistics on freight transport generally give details of the tonnes of goods lifted and the distance over which they are moved, expressed in terms of the product tonne-km. An average tonne of a commodity is usually moved more than once so that in general the tonnes of a commodity lifted in any year by all modes of transport exceeds the tonnage of the commodity produced. To find out how often a commodity is moved it is necessary to know how much is produced as well as how much is lifted.

There are several sources of data on the volume of production of commodities. However they do not cover all commodities. Also they tend to be at a more disaggregated level than the commodity classifications used in freight transport statistics. For example it may be possible to find the physical output of both sugar and confectionery. However these cannot simply be added together when finding the output of the commodity food, since some of the output of sugar will be consumed by the manufacture of confectionary. If they were added together directly some of the Food commodity output would have been double counted since some of its output is used in its own production. The volume of output required for each commodity is the net output of that commodity.

When aggregating physical output data it is desirable to know how much of each commodity is used in the production of all other commodities within the new commodity group. The simplest way to find this would be from a physical input-output table. There are several methods which could be used to obtain physical input-output tables. Perhaps the best method would be to use original sources such as the Census of Production (COP) (Business Statistics Office annual) which have much physical output data. However, some of this data is in the wrong units (e.g. nos of motor cars rather than tonnes of motor cars).

Possibly a simpler method would be to convert existing monetary input-output tables to physical units using price data. Some prices can be obtained for the COP reports when physical volume is measured in tonnes or when the conversion factor from the physical unit (e.g. litres of fuel oil) to tonnes is known. However, it cannot be used where the conversion factor is not known (i.e. for motor cars). There are other possible sources for some commodities, such as the physical volumes of output of commodities as recorded in Central Statistical Office (annual a). However some commodities are not quoted in terms of tonnes (e.g. cars, cutlery, clothing, tyres etc which are usually measured in terms of numbers of items).

Another possible source of price data is the Annual Statement of the Trade of the United Kingdom (Her Majesty's Customs and Excise annual), but it is only useful for competitive imports. However, even within its very disaggregated commodity groupings those things which are imported are often complementary rather than competitive in that they could not be replaced by domestically produced items because of differences in quality, specification etc and consequently may well cost more (or less) than the domestic "equivalent". Where it is expected that both imports and the domestic "equivalents" have the same price this source could be used.

The method of constructing physical input-output tables described in this appendix is one which finds the prices of all commodities at the same time. However, it does entail a substantial degree of estimation and the prices derived should (wherever possible) be checked against any obtained from other sources. If they do not agree the items in the procedure which were estimated should be changed. How this could be done has not been determined.

The appendix contains an example of how the net physical production in 1968 of the eight commodities used in Chapter 1, was found. The method used is then explained mathematically. Details are then given on how a time series of both financial and physical input-output tables could be built up.

A3.2 Example based on 1968

To find the net physical production of eight commodities in 1968, the 1968 input-output tables (Central Statistical Office 1973) were first reduced to 12 categories. The first eight categories correspond as closely as possible to the commodity classification used in Chapter 1. The last four categories were Construction; Gas, electricity and water; Transport; and Distribution and services. All four are either services or their output is not moved by what are considered to be freight transport modes. (The movement of such things as for example water, sewage and gas by pipeline are generally not considered as freight transport since they are only moved in their own pipeline systems). A table showing the correspondences used in reducing the tables is shown in Table A3.1.

Table A3.1 Correspondence between Freight Transport Categories and Input-Output Categories

Freight Transport Categories (as used in Chapter 1)	1968 Input-Output Categories
1 Food, Drink and Tobacco	1,2,6-14
2 Crude Minerals	4,5
3 Coal and Coke	3,15
4 Petroleum and Products	16
5 Chemicals and Fertilisers	17,18,22-25
6 Building Materials	68-71
7 Iron and Steel	26,27,0.5of54
8 Other	19-21,28-53 0.5of54,55-67 72-80
9 Construction	81
10 Gas, Electricity and Water	82-84
11 Transport	85-87
12 Distribution and Services	88-90

The reduced Make, Absorption and Imports tables are given in Tables A3.2 to A3.4.

Table A3.2 Make Matrix 1968

£ million

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.
Food	7236	-	-	-	4	-
Minerals	3	226	-	-	-	8
Coal	-	-	1004	-	2	-
Petrol'm	-	-	-	941	27	-
Chemical	12	-	7	5	2251	-
B. mats.	-	3	-	-	8	1025
Iron & S	-	-	-	-	-	1
Other	1	-	-	1	61	6
Const'n	10	2	10	-	-	11
G.El.& W	-	-	24	3	15	-
Transp't	176	13	2	-	23	29
Dist.& S	119	-	-	-	47	10

Ind'y / Comd'ty	Iron and Steel	Other Manuf	Cons-truc-tion	Gas El.& Water	Trans-port	Dist-rib-&Serv
Food	-	5	-	-	-	-
Minerals	1	-	-	-	-	-
Coal	-	-	-	5	-	-
Petrol'm	-	1	-	-	-	-
Chemical	-	79	-	3	-	-
B. mats.	1	7	15	-	-	-
Iron & S	2127	41	-	-	-	-
Other	54	21925	31	-	-	-
Const'n	8	55	5847	123	26	-
G.El.& W	12	1	-	2181	-	-
Transp't	10	189	-	-	4036	-
Dist.& S	3	276	12	55	7	15306

Table A3.3 Absorption Matrix 1968

£ million

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.
Food	2299	-	-	1	26	1
Minerals	7	4	-	1	10	36
Coal	12	1	139	-	35	27
Petrol'm	61	11	4	51	88	36
Chemical	216	9	8	36	489	27
B. mats.	65	1	4	-	14	81
Iron & S	8	2	33	-	2	7
Other	467	21	96	27	198	105
Const'n	59	8	28	-	5	2
G.El.& W	70	8	42	8	78	39
Transp't	194	3	44	168	97	123
Dist.& S	725	17	14	28	203	83

Ind'y / Comd'ty	Iron and Steel	Other Manuf	Cons-truc-tion	Gas El.& Water	Trans-port	Dist-rib-&Serv
Food	-	60	-	1	22	41
Minerals	26	8	91	15	1	-
Coal	107	46	1	384	1	-
Petrol'm	43	110	29	91	61	45
Chemical	26	562	4	7	1	39
B. mats.	39	126	497	9	11	20
Iron & S	510	1146	156	22	14	2
Other	224	6837	925	121	256	1438
Const'n	3	124	946	35	6	64
G.El.& W	119	271	16	67	43	288
Transp't	102	379	103	66	314	500
Dist.& S	147	1588	232	139	146	1047

Table A3.4 Imports Matrix 1968

£ million

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.
Food	982	-	-	-	15	-
Minerals	1	-	-	584	41	24
Coal	-	-	-	-	-	-
Petrol'm	17	4	1	79	25	9
Chemical	30	2	1	6	161	6
B. mats.	1	-	-	-	1	5
Iron & S	1	-	2	-	-	1
Other	29	1	6	2	41	10
Const'n	-	-	-	-	-	-
G.El.& W	-	-	-	-	-	-
Transp't	-	-	-	-	-	-
Dist.& S	-	-	-	-	-	-

Ind'y / Comd'ty	Iron and Steel	Other Manuf	Cons-truc-tion	Gas El.& Water	Trans-port	Dist-rib-&Serv	Final Dem-and	Total -
Food	-	175	-	-	5	4	1078	2259
Minerals	91	134	1	13	-	-	15	904
Coal	-	-	-	-	-	-	-	-
Petrol'm	9	28	9	27	17	16	54	295
Chemical	5	145	-	2	-	11	59	428
B. mats.	2	12	12	-	-	4	10	47
Iron & S	29	69	21	1	-	-	13	137
Other	39	1637	79	4	22	94	1818	3782
Const'n	-	-	-	-	-	-	-	-
G.El.& W	-	-	-	2	-	-	-	2
Transp't	-	-	-	-	-	-	-	-
Dist.& S	-	-	-	-	-	8	450	2

As illustrated in Figure A3.1, all the material which appears in any commodity initially comes from old scrap (after being used within final demand), imports or primary inputs.

Primary inputs are such things as domestically mined minerals and coal, wood and farm produce. The system boundary for imports and exports can conveniently be taken as the point at which they pass through Customs since they are well documented by Her Majesty's Customs and Excise (annual). The system boundary for primary inputs could be the point at which they are removed from the natural environment. However it is more convenient to take it as the point at which they leave the industry which

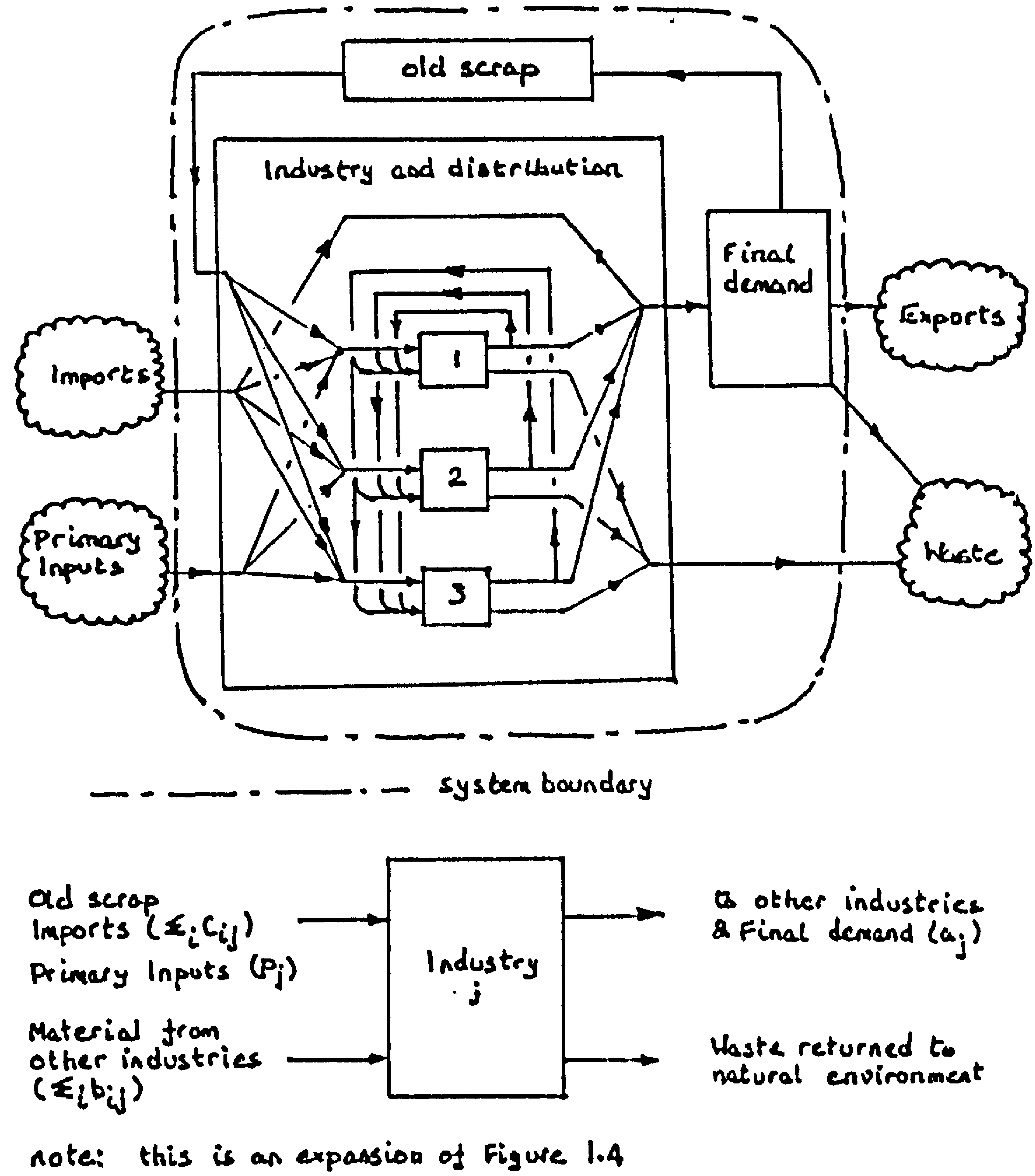

Figure A3.1 Structure of the Industrial and Distribution System

produces them since this is more likely to be reliably documented. The system boundry for waste is the point at which the waste is returned to the natural environment.

As explained below construction of a physical imports table is possible using the same Customs and Excise data from which the original financial imports table was constructed. For simplicity in this exercise the physical imports table was constructed by distributing the total mass of each of the eight physical commodities over the industries in proportion to the financial entries in the table. This was done by dividing all the entries for each commodity by its price. All the prices are shown in Table A3.5.

Table A3.5 Price of Imports 1968

Commodity	£ million		million tonnes		£/tonne
Food	2259		18.8		120.2
Minerals	904		103.5		-
crure oil		584		81.3	7.2
other minerals		320		22.2	14.4
Coal	-		-		-
Petroleum products	295		23.2		12.7
Chemicals	428		1.0		428.0
Building materials	47		8.6		5.5
Iron and Steel	137		3.5		39.1
Other manufactures	3782		9.5		398.1

The one exception was that crude oil was removed from the imports of minerals and treated separately. The complete physical import table is shown in Table A3.6.

The total of all imports used by each industry can be found by summing the columns in Table A3.6. However, this is of no great interest at present because not all inputs to an industry appear in the output of that industry. Many, like coal or petroleum, are consumed by the industry and returned to the natural environment. Others suffer a degree of wastage within the manufacturing process.

A problem to be overcome is that caused by the non-principal products of several industries. These appear as off diagonal entries in the Make Matrix (e.g. £12 millions of chemicals produced by the Food, Drink and Tobacco Industry, see Table A3.2). The problem is caused by the possibility that the various outputs of an industry may require different mixes of inputs, so it is not possible to attribute the commodities absorbed by an industry (Table A3.3) directly to each of its outputs (Table A3.2). A way to overcome this is to construct Make and Absorption tables for industries producing single commodities.

Table A3.6 Physical Imports Matrix 1968

million tonnes

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.
Food	8.2	-	-	-	0.1	-
Minerals	0.1	-	-	81.3	2.8	1.7
Coal	-	-	-	-	-	-
Petrol'm	1.3	0.3	0.1	6.2	2.0	0.7
Chemical	0.1	-	-	-	0.4	-
B. mats.	0.2	-	-	-	0.2	0.9
Iron & S	-	-	0.1	-	-	-
Other	0.1	-	-	-	0.1	-
Const'n	-	-	-	-	-	-
G.El.& W	-	-	-	-	-	-
Transp't	-	-	-	-	-	-
Dist.& S	-	-	-	-	-	-

Ind'y / Comd'ty	Iron and Steel	Other Manuf	Cons-truc-tion	Gas El.& Water	Trans -port	Dist-rib-&Serv	Final Dem-and	Total -
Food	-	1.5	-	-	0.1	-	9.0	18.8
Minerals	6.3	9.3	0.1	0.9	-	-	1.0	103.5
Coal	-	-	-	-	-	-	-	-
Petrol'm	0.7	2.2	0.7	2.1	1.3	1.3	4.2	23.2
Chemical	-	0.3	-	-	-	-	0.1	1.0
B. mats.	0.4	2.2	2.2	-	-	0.7	1.8	8.6
Iron & S	0.7	1.8	0.5	-	-	-	0.3	3.5
Other	0.1	4.1	0.2	-	0.1	0.2	4.6	9.5
Const'n	-	-	-	-	-	-	-	-
G.El.& W	-	-	-	-	-	-	-	-
Transp't	-	-	-	-	-	-	-	-
Dist.& S	-	-	-	-	-	-	-	-

With these highly aggregated tables there were only six elements off the leading diagonal in the make matrix (Table A3.2) which were larger than the corresponding elements in the absorption matrix (Table A3.3). Of these six only one was within the physical commodities section of the table. It seemed to me that a simple way of constructing an absorption table for single commodity industries would be to subtract the make matrix from the absorption matrix, and to leave the leading diagonal blank. The table would then describe the net quantities of each commodity absorbed by each industry. The corresponding net quantity of each commodity produced would be found by subtracting the elements of the leading diagonal in the absorption matrix from the corresponding elements in the make matrix. The resulting two net or modified matrices are shown in Tables A3.7 and A3.8.

Table A3.7 Modified Make Matrix 1968

£ million

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.
Food	4937	-	-	-	-	-
Minerals	-	222	-	-	-	-
Coal	-	-	865	-	-	-
Petrol'm	-	-	-	889	-	-
Chemical	-	-	-	-	1762	-
B. mats.	-	-	-	-	-	944
Iron & S	-	-	-	-	-	-
Other	-	-	-	-	-	-
Const'n	-	-	-	-	-	-
G.El.& W	-	-	-	-	-	-
Transp't	-	-	-	-	-	-
Dist.& S	-	-	-	-	-	-

Ind'y / Comd'ty	Iron and Steel	Other Manuf	Cons-truc-tion	Gas El.& Water	Trans -port	Dist-rib- &Serv
Food	-	-	-	-	-	-
Minerals	-	-	-	-	-	-
Coal	-	-	-	-	-	-
Petrol'm	-	-	-	-	-	-
Chemical	-	-	-	-	-	-
B. mats.	-	-	-	-	-	-
Iron & S	1616	-	-	-	-	-
Other	-	15088	-	-	-	-
Const'n	-	-	4900	-	-	-
G.El.& W	-	-	-	2114	-	-
Transp't	-	-	-	-	3722	-
Dist.& S	-	-	-	-	-	14252

Table A3.8 Modified Absorption Matrix 1968

£ million

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.
Food	-	-	-	1	22	1
Minerals	4	-	-	1	10	28
Coal	12	1	-	-	33	27
Petrol'm	61	11	4	-	61	36
Chemical	204	9	1	31	-	27
B. mats.	65	-2	4	-	6	-
Iron & S	8	2	33	-	2	6
Other	466	21	96	26	137	99
Const'n	49	6	18	-	5	-9
G.El.& W	70	8	18	5	63	39
Transp't	18	-10	42	168	74	94
Dist.& S	606	17	14	28	156	73

Ind'y / Comd'ty	Iron and Steel	Other Manuf	Cons-truc-tion	Gas El.& Water	Trans -port	Dist-rib-&Serv
Food	-	55	-	1	22	41
Minerals	25	8	91	15	1	-
Coal	107	46	1	379	1	-
Petrol'm	43	109	29	91	61	45
Chemical	26	483	4	4	1	39
B. mats.	38	119	482	9	11	20
Iron & S	-	1105	156	22	14	2
Other	170	-	894	121	256	1438
Const'n	-4	69	-	-88	-20	64
G.El.& W	107	270	16	-	43	288
Transp't	92	190	103	66	-	500
Dist.& S	144	1312	220	84	139	-

The single commodity industry absorption table is in effect a commodity by commodity table. A more sophisticated method of constructing a commodity by commodity absorption matrix has been developed by Clopper Almon (1970). It is based upon the commodity technology assumption. Almon's method could be used in any future analyses and is described below (see Section A3.4).

To convert the modified absorption matrix to physical units the elements for each commodity were divided by that commodity's price. However, before the price of each commodity could be found the net physical volume of production of each commodity, corresponding to the financial elements in the modified make matrix, had to be found.

Estimates of the proportion of each commodity absorbed by an industry which appeared in the output of that industry are given in Table A3.9.

Table A3.9 Use Coefficients

(Proportion of commodity i absorbed by industry j which appears in the output of industry j)

Ind'y Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.	Iron and Steel	Other Manuf
Food	1	-	-	-	-	-	-	-
Minerals	-	1	-	.9	.8	.8	.8	.8
Coal	-	-	1	-	-	-	-	-
Petrol'm	-	-	-	1	.5	-	-	-
Chemical	-	-	-	.5	1	.8	.4	.8
B. mats.	-	-	-	-	-	1	-	-
Iron & S	-	-	-	-	-	.9	1	.9
Other	-	-	-	.5	.9	.9	-	1

These proportions may seem high but it must be remembered that any new scrap which was produced by an industry and returned to another industry was part of the output of the first industry. The difference (1 - use coefficient) is the proportion of the commodity absorbed by an industry, which it returned to the natural environment.

To find the quantity of imports appearing in the output of each industry it was necessary to multiply the elements of the physical imports matrix (Table A3.6) by the corresponding elements of the Use matrix (Table A3.9). The result of doing this is shown in Table A3.10.
The total imports appearing in the output of each industry were found by summing each column and are also shown in Table A3.10.

Table A3.10 Imports which appear in the Outputs of Industries

million tonnes

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.	Iron and Steel	Other Manuf
Food	8.2	-	-	-	-	-	-	-
Minerals	-	-	-	73.2	2.2	1.4	5.0	7.4
Coal	-	-	-	-	-	-	-	-
Petrol'm	-	-	-	6.2	1.0	-	-	-
Chemical	-	-	-	-	0.4	0.9	-	0.2
B. mats.	-	-	-	-	-	-	-	-
Iron & S	-	-	-	-	-	-	0.7	1.6
Other	-	-	-	-	0.1	-	-	4.1
Total	8.2	-	-	79.4	3.7	2.3	5.7	13.3

Since the volume of production of primary inputs is generally measured at the point at which they leave their respective industries they were assumed to appear in the output of those industries without loss. In this analysis old scrap was ignored due to lack of data. The totals of primary inputs and imports which appeared in the outputs of industries are shown in Table A3.11.

Table A3.11 Primary Inputs and Imports appearing in the Output of Industries

million tonnes

Industry	Primary Inputs	Imports	Total
Food	72.1	8.2	80.3
Minerals	314.9	-	314.9
Coal	171	-	171
Petroleum	-	79.4	79.4
Chemicals	-	3.7	3.7
Building materials	-	2.3	2.3
Iron and Steel	-	5.7	5.7
Other	1.2	13.3	14.5

The imports and primary inputs shown in Table A3.11 appeared in the outputs of these industries. However as shown in Figure A3.1, some of the output of other industries was also absorbed by each industry. The proportion of the output of each industry absorbed by the other industries was found for each commodity by dividing the elements in that row of the modified absorption matrix by the net output of that commodity given in the modified make matrix. The resulting matrix is shown in Table A3.12.

Table A3.12 Commodity i absorbed by Industry j per unit of Output of Industry i

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.	Iron and Steel	Other Manuf
Food	-	-	-	-	.004	-	-	.011
Minerals	.018	-	-	.005	.045	.126	.117	.036
Coal	.014	.001	-	-	.038	.031	.124	.053
Petrol'm	.069	.012	.004	-	.069	.040	.048	.122
Chemical	.116	.005	.001	.018	-	.015	.015	.274
B. mats.	.069	-.002	.004	-	.006	-	.040	.126
Iron & S	.005	.001	.020	-	.001	.004	-	.684
Other	.030	.001	.006	.002	.009	.007	.011	-

Some of the commodities absorbed also appear in the outputs of the respective industries. The proportions absorbed which appeared in the outputs are those given in the Use matrix (Table A3.9).

As in the case of imports, the proportion of the net output of an industry which appeared in the output of another industry was found by multiplying the elements of the use matrix by the elements of the matrix shown in Table A3.12. The result of doing this is shown in Table A3.13.

Table A3.13 Proportion of the Output of Industry i which appears in the Output of Industry j

App'rs in Output of Industry / Proportion of Output of Ind'try	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.	Iron and Steel	Other Manuf
Food								
Minerals	-	-	-	.004	.036	.101	.090	.029
Coal	-	-	-	-	-	-	-	-
Petrol'm	-	-	-	-	.034	-	-	-
Chemical	-	-	-	.009	-	.012	.006	.219
B. mats.	-	-	-	-	-	-	-	-
Iron & S	-	-	-	-	-	.003	-	.615
Other	-	-	-	.001	.008	.006	-	-

The flow of imports and primary inputs was then followed through the productive process as shown in Table A3.14.

Table A3.14 Industrial Output

million tonnes

	Outp. prev. round	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.	Iron and Steel	Other Manuf
Primary Inputs & Imports	-	80.3	314.9	171	79.4	3.7	2.3	5.7	14.5
Food	80.3	-	-	-	-	-	-	-	-
Minerals	314.9	-	-	-	1.3	11.3	31.8	28.3	9.1
Coal	171.0	-	-	-	-	-	-	-	-
Petrol'm	79.4	-	-	-	-	2.7	-	-	-
Chemical	3.7	-	-	-	-	-	-	-	0.8
B. mats.	2.3	-	-	-	-	-	-	-	-
Iron & S	5.7	-	-	-	-	-	-	-	3.5
Other	14.5	-	-	-	-	0.1	0.1	-	-
Petrol'm	1.3	-	-	-	-	-	-	-	-
Chemical	14.1	-	-	-	0.1	-	0.2	0.1	3.1
B. mats.	31.9	-	-	-	-	-	-	-	-
Iron & S	28.3	-	-	-	-	-	0.1	-	17.4
Other	13.4	-	-	-	-	0.1	0.1	-	-
Petrol'm	0.1	-	-	-	-	-	-	-	-
Chemical	0.1	-	-	-	-	-	-	-	-
B. mats.	0.4	-	-	-	-	-	-	-	-
Iron & S	0.1	-	-	-	-	-	-	-	0.1
Other	20.5	-	-	-	-	0.2	0.1	-	-
Chemical	0.2	-	-	-	-	-	-	-	-
B. mats.	0.1	-	-	-	-	-	-	-	-
Other	0.1	-	-	-	-	-	-	-	-
Total	-	80.3	314.9	171	80.8	18.1	34.7	34.1	48.5

The first material which appeared in the output of each industry is shown in the first row. However some of this output appeared in the output of other industries. The figures in the first row were transfered to the first column. These were then multiplied by the row of corresponding elements in Table A3.13. This led to further output by some industries. Again some of this further output also appeared in the output of other industries so totals of the further production of each industry for this round were transfered to the first column again and the process was repeated. The total net production of each industry was then found by summing each column. The reason why this process stops is given below in the section on the mathematical derivation of this method (see Section A3.3).

The prices of domestically produced commodities were found by dividing the value of net production from the modified make matrix (Table A3.7) by the net quantities produced (Table A3.14). The result of doing this is shown in Table A3.15.

Table A3.15 Price of Domestically Produced Commodities 1968

Commodity	£ million	million tonnes	£/tonne	Imports £/tonne	
Food	4937	80.3	61.5	120.2	
Minerals	222	314.9	0.7	14.4	
Coal	865	171.0	5.1	-	
Petroleum		889	80.8	11.0	7.2 crude
					12.7 products
Chemicals	1762	18.1	97.3	428.0	
Building materials	944	34.7	27.2	5.5	
Iron and Steel	1616	34.1	47.4	39.1	
Other	15088	48.5	311.1	398.1	

For comparison the prices of imports are also shown. As previously mentioned the modified make matrix was found in physical units by dividing the elements of the matrix in financial units (Table A3.8) by the corresponding commodities' prices (Table A3.15). The result is shown in Table A3.16.

To find the supply of each commodity within the economy it was necessary to add to the net domestic production of each commodity the amount of that commodity imported. However to avoid double counting the amount of commodity imported by the industry which produced that commodity was first subtracted. The total supply of the eight commodities in 1968 is shown in Table A3.17.

One of the sources of error in this estimate of the net domestic production of commodities was the very high level of aggregation. Consequently the implied assumption of a constant price for each commodity to every industry is very doubtful. In future work the level of disaggregation used should be as low as feasible, at which the constant

Table A3.16 Modified Absorption Matrix 1968

million tonnes

Ind'y / Comd'ty	Food Drink &Tob.	Crude Min.	Coal and Coke	Pet. and Prods	Chem. and Fert.	Build Mats.
Food	-	-	-	-	0.4	-
Minerals	5.7	-	-	1.4	14.2	39.7
Coal	2.4	0.2	-	-	6.5	5.3
Petrol'm	5.5	1.0	0.4	-	5.5	3.3
Chemical	2.1	0.1	-	0.3	-	0.3
B. mats.	2.4	-0.1	0.1	-	0.2	-
Iron & S	0.2	-	0.7	-	-	0.1

Ind'y / Comd'ty	Iron and Steel	Other Manuf	Cons-truc-tion	Gas El.& Water	Trans-port	Dist-rib-&Serv
Food	-	0.9	-	-	0.4	0.7
Minerals	35.5	11.3	129.1	21.3	1.4	-
Coal	21.3	9.1	0.2	74.9	0.2	-
Petrol'm	3.9	9.9	2.6	8.3	5.5	4.1
Chemical	0.3	5.0	-	-	-	0.4
B. mats.	1.4	4.4	17.7	0.3	0.4	0.7
Iron & S	-	23.3	3.3	0.5	0.3	-

Table A3.17 Total Supply of Commodities 1968

million tonnes

Commodity	Imports	Import used by same industry	Remaining Imports	Domestic Production	Total
Food	18.8	8.2	10.6	80.3	90.5
Minerals	22.2	-	22.2	314.9	337.1
Coal	-	-	-	171.0	171.0
Petroleum	104.5	87.5	17.0	80.8	97.8
Chemicals	1.0	0.4	0.6	18.1	18.7
Building materials	8.6	0.9	7.7	34.7	42.4
Iron and Steel	3.5	0.7	2.8	34.1	36.9
Other	9.5	4.1	5.4	48.5	53.9

price assumption would be more valid. Any aggregation required to commodity categories corresponding to those used in freight transport statistics would only be made after the physical make and absorption tables had been produced. In the process of aggregation non-zero elements will appear off the leading diagonal of the absorption matrix. Both the make and absorption matrices will be converted to net tables by subtracting the leading diagonal of the absorption matrix from both matrices.

A3.3 Mathematics of the method used to find net physical production

To greatly simplify the analysis we will assume single product industries. (Section A3.4 below explains a method for producing a commodity by commodity absorption table which is effectively a single product industry absorption table. As an aid to comprehension this section is written in terms of single product industries.) One of the implications of the single product assumption is that no industry produces re-cycleable new scrap. Any scrap which is produced is waste which is returned to the natural environment.

The material for all commodities produced initially comes from old scrap, imports and primary inputs (see Figure A3.1). The total of imports going into industry are

$$\sum_{i=1}^{n} C_{ij} \qquad j=1,n$$

where C_{ij} is the import of commodity i by industry j for all i and j. However not all of the imports going into the j^{th} industry will appear in its output. The remainder is wasted and returns to the environment.

If we let

U_{ij} = proportion of commodity i absorbed by industry j and which appears in the output of industry j (the "use" coefficient) $\qquad i=1,n$
$j=1,n$

Then the total of all imports by the j^{th} industry which appear in its output will be

$$\sum_{i=1}^{n} U_{ij}C_{ij} \qquad j=i,n$$

A conventional assumption can be made that primary inputs first appear in the industry producing that commodity without any loss.

Let:

P_i = primary input of commodity i (to industry i) $i=1,n$

and h_j = imports and primary input appearing in the output of industry j $j=1,n$

Then

$$h_j = P_j + \sum_{i=1}^{n} U_{ij}C_{ij} \qquad j=1,n \qquad \text{(A3.1)}$$

So far old scrap has been excluded from the analysis but it could be included as a further term in equation A3.1.

The total of domestically produced commodities appearing in the output of industry j is

$$\sum_{i=1}^{n} U_{ij}b_{ij} \qquad j=1,n$$

where U_{ij} is as before and

b_{ij} = absorption of commodity i by industry j $i=1,n$; $j=1,n$

However $U_{ij}b_{ij}$ can be expressed in terms of the proportion of the output of commodity i which appears in the output of industry j for all i and j.

Let

a_i = net output of commodity i $i=1,n$

W_{ij} = the proportion of the output of commodity i which appears in the output of industry j $i=1,n$; $j=1,n$

then

$$U_{ij}b_{ij} = W_{ij}a_i \qquad i=1,n;\ j=1,n \qquad \text{(A3.2)}$$

$$\therefore \quad W_{ij} = U_{ij}b_{ij}/a_i \qquad i=1,n;\ j=1,n \qquad \text{(A3.3)}$$

So far all quantities (a_i, b_{ij}, C_{ij}, P_i, h_i) are in terms of mass. However make and absorption tables are usually expressed in monetary terms. It is possible (see example above and/or the next section) to construct in monetary terms a make matrix with elements a'_{ij} and an absqrption matrix with elements b'_{ij}.

where

$$a'_{ij} = 0 \qquad i=1,n \; i \neq j, \quad j=1,n$$

and $$b'_{ii} = 0 \qquad i=1,n$$

That is all industries only make one commodity and do not absorb any of that commodity. It is also possible to assume that

$$b_{ij}/a_i = b'_{ij}/a'_{ii} \qquad i=1,n \quad j=1,n$$

then from equation A3.3

$$W_{ij} = U_{ij}b'_{ij}/a'_{ii} \qquad i=1,n \quad j=1,n \qquad (A3.4)$$

(As will be seen later this implies that the price paid by all industries for a commodity is the same). From equation A3.2

$$\sum_{i=1}^{n} U_{ij}b_{ij} = \sum_{i=1}^{n} W_{ij}a_i \qquad j=1,n$$

The output of each industry consists of imports, primary inputs and other commodities.

$$a_j = \sum_{k=1}^{n} U_{kj}C_{kj} + P_j + \sum_{k=1}^{n} U_{kj}b_{kj}$$

$$= h_j + \sum_{k=1}^{n} a_k W_{kj} \qquad j=1,n$$

or $\quad a^T = h^T + a^T W$

where a^T and h^T are row vectors whose elements are

$$a_i \text{ and } h_i \qquad i=1,n$$

respectively, and W is the matrix whose elements are

$$W_{ij} \qquad i=1,n \quad j=1,n$$

$$a^T (I - W) = h^T \tag{A3.5}$$

or $\quad a^T = h^T (I - W)^{-1}$

Alternatively, continuing from equation A3.1, for all j some of h_j appears in the output of other industries. That is

$h_i W_{ij}$ $\qquad$ $i=1,n$

appears in the output of industry j $\qquad$ $j=1,n$.

Over all commodities there will be an extra

$\sum_{i=1}^{n} h_i W_{ij}$ in the output of industry j, or for all

industries the extra output will be $h^T W$.

However some of this extra output will appear in yet more industries output and this will amount to

$h^T W^2$

This process can be repeated until we have

$$a^T = h^T (I + W + W^2 + W^3 + \ldots)$$

$$= h^T (I - W)^{-1} \tag{A3.6}$$

This second derivation is the same as the method used in the previous numerical example. The row sums in W all sum to less than one. Consequently the series

$I + W + W^2 + W^3 + \ldots$ will converge.

To find the size of the elements b_{ij} we can use equation A3.2 to get

$b_{ij} = W_{ij} a_i / U_{ij}$ $\qquad$ $i=1,n$
$j=1,n$

but from equation A3.4

$W_{ij} = U_{ij} b'_{ij} / a'_{ii}$ $\qquad$ $i=1,n$
$j=1,n$

$\therefore \quad b_{ij} = (U_{ij} b'_{ij} / a'_{ii})(a_i / U_{ij}) = b'_{ij}(a_i / a'_{ii})$ $\qquad$ $i=1,n$
$j=1,n$

To find b_{ij} we divide b'_{ij} by the price a'_{ii}/a_i for all i and j. As mentioned above this implies that the price of a commodity is the same for all industries.

A3.4 Construction of a commodity by commodity absorption table

The following method of constructing a commodity by commodity absorption matrix was developed by Clopper Almon (1970). The method is based upon the Commodity technology assumption. That is that all the industries which produce a Commodity use the same technology to do so. Consequently all industries require the same mix of inputs for a given commodity.

If B is the absorption matrix, where element b_{ij} is the input of commodity i to industry j

A is the market share matrix, where element a_{ij} is the fraction of commodity i made by industry j so that

$$\sum_{j=1}^{n} a_{ij} = 1 \qquad i=1,n \qquad (A3.6)$$

and B' is the modified or pure absorption matrix where element

b'_{ij} is the input of commodity i into commodity j.

Then B = B'A

$$\text{or} \quad b_{ij} = \sum_{l=1}^{n} b'_{il}a_{lj} \qquad i=1,n \quad j=1,n \qquad (A3.7)$$

$$\text{so} \quad B' = BA^{-1} \qquad (A3.8)$$

However equation A3.8 leads to some small elements (some of which are negative) in B' which were zero in B. It is possible to use a modified form of iterative procedure for the solution of equation A3.8 which avoids negative elements in B'.

From equation A3.7

$$0 = B - B'A$$

and adding B' to both sides

$$B' = B + B'\,(I - A)$$

or $$b'_{ij} = b_{ij} + b'_{ij} - \sum_{l=1}^{n} b'_{il}a_{lj} \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array} \qquad \text{(A3.9)}$$

$$b'_{ij} = b_{ij} - \sum_{\substack{l=1 \\ l \neq j}}^{n} b'_{il}a_{lj} + b'_{ij}(1 - a_{jj}) \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array} \qquad \text{(A3.10)}$$

Or in words, the quantity of commodity i used in the manufacture of commodity j is equal to the quantity of commodity i used by industry j <u>less</u> the use of commodity i by industry j for commodities other than j <u>plus</u> commodity i used for commodity j in industries other than j, for all i and j.

Both sides of equation A3.6 can be multiplied by b'_{ij} to get

$$b'_{ij}\,(a_{jj} + \sum_{\substack{l=1 \\ l \neq j}}^{n} a_{jl}) = b'_{ij} \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array}$$

$$b'_{ij} \sum_{\substack{l=1 \\ l \neq j}}^{n} a_{jl} = b'_{ij}\,(1 - a_{jj}) \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array} \qquad \text{(A3.11)}$$

Equation A3.11 says that

$$b'_{ij} \sum_{\substack{l=1 \\ l \neq j}}^{n} a_{jl}$$

the amount of commodity i removed via the second terms in the set of equations A3.10 from other industries due to their production of commodity j is exactly equal to that added via the third term to industry j's consumption of commodity i ($b'_{ij}(1-a_{jj})$), for all i and j.

Substituting equation A3.11 in equation A3.10

$$b'_{ij} = b_{ij} - \sum_{\substack{l=1 \\ l \neq j}}^{n} b'_{il} a_{lj} + b'_{ij} \sum_{\substack{l=1 \\ l \neq j}}^{n} a_{jl} \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array} \qquad (A3.12)$$

It is unlikely that half or more of a commodity will be produced in industries other than that for which the commodity is the principal product. Consequently the row sums of the absolute values of (I - A) will be less than one and the iterative process for the solution of equation A3.12 will converge. The first approximation to b'_{ij}

is $b(0)'_{ij} = b_{ij}$ $\quad i=1,n \quad j=1,n$

$$\text{then } b(k+1)'_{ij} = b_{ij} - \sum_{\substack{l=1 \\ l \neq j}}^{n} b(k)'_{il} a_{lj} + b(k)'_{ij} \sum_{\substack{l=1 \\ l \neq j}}^{n} a_{jl} \qquad i=1,n \qquad (A3.13)$$

To ensure that $b(k+1)'_{ij} \geq 0$ $\quad i=1,n \quad j=1,n$ we can modify

equation A3.13 such that

$$b_{ij} - f_{ij} \sum_{\substack{l=1 \\ l \neq j}}^{n} b(k)'_{ij} a_{lj} \geq 0 \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array}$$

$$\text{where } f_{ij} = 1, \text{ if } b_{ij} \geq \sum_{\substack{l=1 \\ l \neq j}}^{n} b(k)'_{il} a_{lj} \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array}$$

$$\text{and } f_{ij} = b_{ij} \Big/ \sum_{\substack{l=1 \\ l \neq j}}^{n} b(k)'_{il} a_{lj}, \text{ if } b_{ij} < \sum_{\substack{l=1 \\ l \neq j}}^{n} b(k)'_{il} a_{lj} \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array}$$

$$\text{or } f_{ij} = \text{minimum of } \Big(b_{ij} \text{ and } \sum_{\substack{l=1 \\ l \neq j}}^{n} b(k)'_{il} a_{lj}\Big) \Big/ \sum_{\substack{l=1 \\ l \neq j}}^{n} b(k)'_{il} a_{lj} \qquad \begin{array}{l} i=1,n \\ j=1,n \end{array}$$

(A3.14)

The effect of f_{ij} (when $f_{ij} < 1$) is to reduce, from the otherwise expected level, the quantity of commodity i used in industry j for the production of all commodities except j, by equal amounts.

The amount of commodity i used by industry q for the production of commodity p is

$$f_{iq} b(k)'_{ip} a_{pq} \qquad i=1,n \quad p=1,n \quad q=1,n$$

The amount of commodity i used by industry q for the production of all commodities except q is

$$\sum_{\substack{p=1 \\ p \neq q}}^{n} f_{iq} b(k)'_{ip} a_{pq} = f_{iq} \sum_{\substack{p=1 \\ p \neq q}}^{n} b(k)'_{ip} a_{pq} \qquad i=1,n \quad q=1,n \tag{A3.15}$$

The amount of commodity i used by industries other than p for the production of commodity p is

$$\sum_{\substack{q=1 \\ q \neq p}}^{n} f_{iq} b(k)'_{ip} a_{pq} = b(k)'_{ip} \sum_{\substack{q=1 \\ q \neq p}}^{n} f_{iq} a_{qp} \qquad i=1,n \quad p=1,n \tag{A3.16}$$

We can replace the second and third terms in A3.13 by A3.15 and A3.16 if we exchange j for q in A3.15 and j for p in A3.16. Then

$$b(k+1)'_{ij} = b_{in} - f_{ij} \sum_{\substack{p=1 \\ p \neq j}}^{n} b(k)'_{ip} a_{pj} + b(k)'_{ij} \sum_{\substack{q=1 \\ p \neq j}}^{n} j_{iq} a_{jq} \qquad i=1,n \quad j=1,n \tag{A3.17}$$

The calculation of b(k+1)' is now a two pass process involving first the calculation of all f_{ij} using equation A3.14 and then the use of equation A3.17.

An exactly analogous procedure can also be used to calculate a commodity by commodity imports matrix.

The pure make matrix corresponding to the pure absorption matrix will consist of a matrix whose only elements are a leading diagonal of the total production of each commodity. The pure absorption table will contain non-zero elements on the leading diagonal. To obtain pure make and absorption tables for the net production of each commodity the leading diagonal of the absorption table can be subtracted from both tables.

A problem which I have not resolved with this procedure is that some industries produce new scrap. For example the motor vehicle industry produces scrap steel. However it does not use the same inputs to do so as the iron and steel industry uses to produce steel. A possible solution to this problem is that the factors f_{ij} might reduce the quantity of inputs to steel to those used by the steel industry.

A3.5 Finding input-output tables for years intermediate to those for which firm tables exist

There are firm input-output tables for the years 1954 (Central Statistical Office 1961), 1963 (CSO 1970), 1968 (CSO 1973) and 1974 (CSO 1981). The three tables of interest are the Make, Absorption and Imports tables. Of these the imports table will be dealt with separately later in this section.

For years other than those indicated above the row and column totals are known or can be inferred form the Blue Book (CSO annual b) and from 1969 from the Annual Census of Production (Business Statistics Office annual). To obtain updated tables it would be possible to use the RAS method with the nearest adjacent firmly based table. However as Johnson and Lynch (1975) found when applying the RAS method to update the 1963 tables to 1968 there would be serious discontinuities in the time series of the elemens of the tables at the points at which the change over from one firm table to the next were made. To overcome this difficulty a process of linear interpolation between the two adjacent firm tables could be used to construct base matrices to which RAS could be applied.

The RAS procedure is reversible. That is from on matrix as base, another set of row and column totals can be used to produce a second matrix. Then using the second matrix with the row and column totals for the first matrix it is possible to return to the first matrix. The effect of this reversibility is that there are families of similar matrices from any of which the same matrix will be produced using a given set of row and column totals. Specifically any linear multiple of a matrix is in the same family of similar matrices and can be used instead of the original matrix as base matrix in the RAS procedure.

Consequently, to obtain compatible tables between which to make interpolations, the tables can all be reduced to a common basis. This reduction can be achieved by dividing every element in a table by the sum of all elements. In every reduced table the sum of all elements will be equal to one.

To obtain base matrices for the intermediate years linear interpolations could be made for every element between the corresponding elements in the two adjacent reduced firm tables. The sum of all elements in these interpolated base matrices will also be equal to one.

As a test of this procedure tables for 1963 could be constructed using the tables for 1954 and 1968 for interpolation of the base tables and the actual row and column sums from the 1963 tables. The elements of the resulting tables would then be compared with the actual elements in the firm tables for 1963. A similar comparison would also be possible for 1968.

Imports table

The basic sources of data for constructing imports tables are the statistics collected by HM Customs and Excise (annual). These statistics have a very fine breakdown into different commodities and usually both the value and quantity are recorded. For most categories of import it is possible to specify which industry was responsible for its import. Consequently a correspondence table between the Customs and Excise Commodity classification and the individual elements of the imports matrix can be constructed. Using this correspondence table and the import statistics it would be possible to construct both monetary and physical imports tables.

A3.6 Sources of Data

As explained above the basic source of data for the construction of a time series of financial make and absorption tables would be the firmly based tables produced by CSO (1961, 1970, 1973, and 1981). These could be further augmented by data on industrial production for intermediate years from the Blue Book (CSO annual b) and the Annual Census of Production (Business Statistics Office annual). The basic source of data for the construction of imports tables would be the Annual Statement of the Trade of the United Kingdom (Her Majesty's Customs and Excise annual).

Primary inputs comprise the products of agriculture, forestry, fishing and mining. Details in physical quantities of all these are given in the Annual Abstract of Statistics (CSO annual a). The figures are also available in Agricultural Statistics for the United Kingdom (Ministry of Agriculture Fisheries and Food annual a), Output and Utilisation of Farm Produce in the United Kingdom (MAFF annual b), Sea fisheries Statistical Tables (MAFF annual c), United Kingdom Mineral Statistics (Institute of Geological Sciences annual) and Digest of United Kingdom Energy Statistics (Department of Energy annual). I have found no sources for such primary inputs as water and gases abstracted from the atmosphere. Nor do I know of any sources of data for the consumption of old scrap for final demand.

APPENDIX 4. A HALF HOURLY ELECTRICITY SYSTEM MODEL

A4.1 History of the Model

The half hourly electricity system model used in the vehicle refuelling infrastructure study (Chapter 2) was based on an hourly electricity system model developed by Mellish and Baker (1977). This previous model was first used to determine long and short run marginal costs for different electricity consumers (Energy Research Group 1976) and later to examine the integration of wavepower into the electricity system (Vimukta, Baker and Plumpton 1978). For a given set of annual sectoral electricity sales, the aim of the model is to estimate the total demand for each half hour (previously hour) period in the year. From this can be derived an annual load duration curve.

A4.2 Structure

The structure of the model is largely determined by the data available. Briefly the total demand at any time is taken to be the sum of demands for a number of sectors. For each sector the demand is taken to be the yearly average demand multiplied by a seasonal factor and by a time of day factor. Information for the time of day factors was obtained from the Electricity Council's grid load curve analysis (Rhys 1980). For the seasonal factors information was obtained from Energy Trends (Department of Energy, monthly).

Sectors

The current version of the model has five sectors. These are Domestic on-peak, Commercial, Industrial, Domestic off-peak and Electric vehicle battery recharging. In principal there can be any number of sectors and for the remainder of the model description I will in general take this number to be n.

Seasonal factors

There is very little data readily available on the seasonal variation in electricity demand on a sectoral basis. For the Domestic, Commercial and Industrial sectors it only amounts to quarterly sales to each (Department of Energy, monthly). What is required is an estimate of the ratio between daily average load and annual average load for each sector. This is obtained by fitting a fourier series to the available data (see section A4.3 below).

Daily factors

Typical daily loads for different sectors are available from the Electricity Council's grid load curve analysis (Rhys 1980). Each year the Electricity Council carries out an analysis of grid load curve data for a number of days. Multiple regression techniques are used to resolve the total half-hourly demands for each day into domestic, commercial and industrial components.

From this analysis I obtained factors which express half hourly loads as a fraction of the day's average load, for each sector for both a winter's and a summer's day. To obtain the daily pattern for other times of year I assumed that a sinusoidaly varying mix of these two can be taken. The summer and winter weighting factors are shown in Figure A4.1.

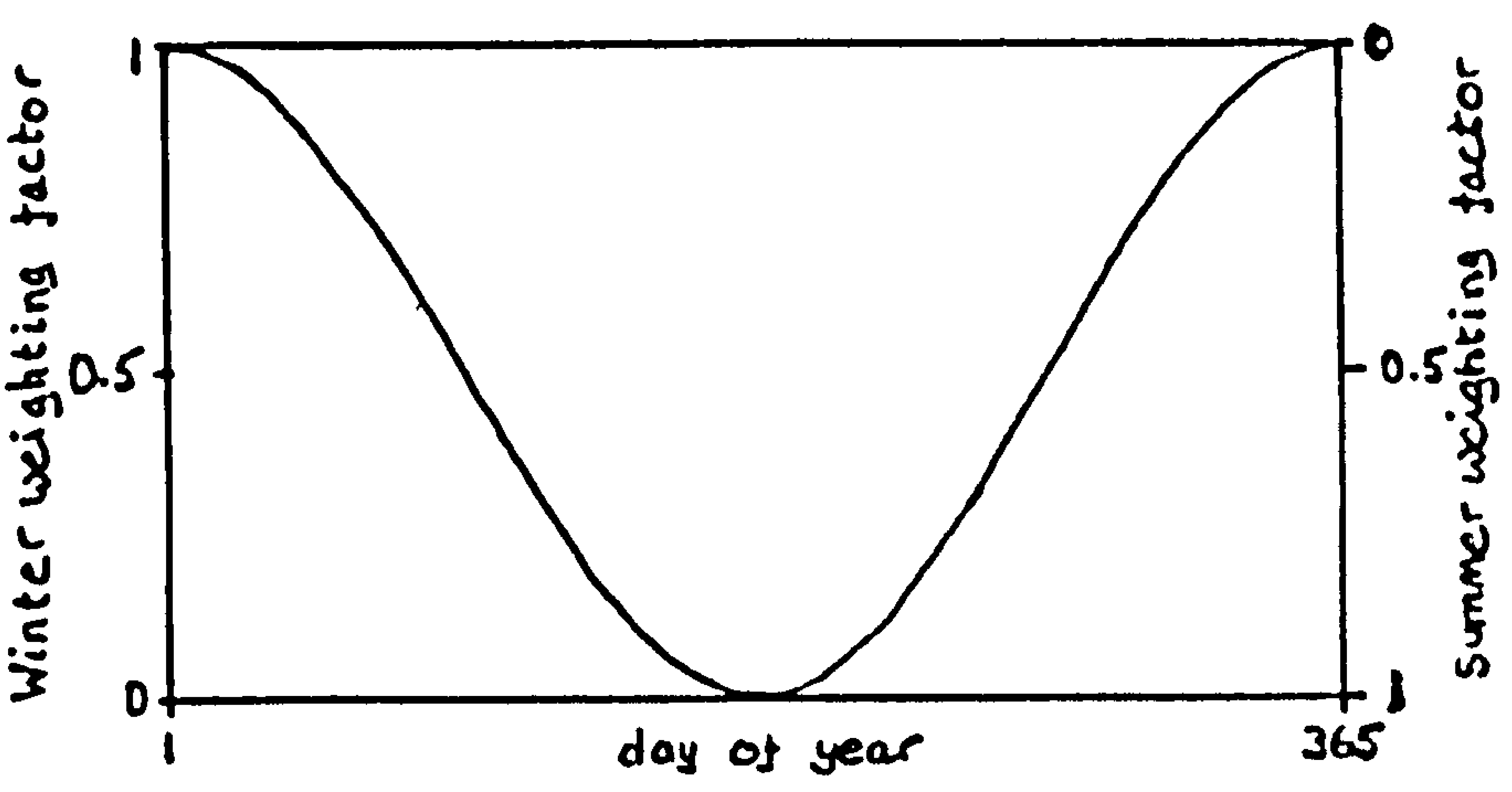

Figure A4.1 Winter and Summer daily weighting factors

Mathematical formulation

If we let:

s = sector index $(1,n)$
$l_s(h,t)$ = load due to sector s at time h on day t
D_s = average load due to sector s
$f(h)_{st}$ = load s at time h on day t as a proportion of its daily average
$f(h)_{sw}$ = $f(h)_{st}$ for mid winter day
$f(h)_{ss}$ = $f(h)_{st}$ for mid summer day
i = seasonal factor index $(1,p)$
A_{si}, B_{si} = seasonal factors for sector s
$L(h,t)$ = total load at time h on day t
c_{it} = $\cos(2\pi it/365)$
s_{it} = $\sin(2\pi it/365)$

then

$$f(h)_{st} = 0.5(f(h)_{sw}(1 + c_{1t}) + f(h)_{ss}(1 + c_{1(t+365/2)}))$$

$$l_s(h,t) = D_s(1 + \sum_{i=1}^{p} (A_{si}c_{it} + B_{si}s_{it}))f(h)_{st}$$

$$L(h,t) = \sum_{s=1}^{n} l_s(h,t)$$

Load Duration Curves

I have used the above model of half hourly electricity loads in a computer programme to calculate the average and maximum loads on the electricity system and a load duration curve for any given set of average demands for the five demand sectors. The programme also finds these loads and the load duration curve with the off peak loads spread throughout the day so that they fill the troughs in the daily demand. This I have called logic load. It also finds these things for an electricity system which has a system store to remove variations in demand for each day. I assumed that the store has an efficiency of 80%, and the programme also calculates the size of this system store.

A4.3 Fourier Series

In Fourier analysis a fourier series is usually fitted to a set of points. A series with N terms will exactly fit N points. However the data available for estimating the terms of the fourier series for the seasonal factors are histograms. These are the quarterly sales data for sales to the domestic, industrial and commercial sectors, and monthly averages for off peak and vehicle battery recharging.

If we let z be a seasonally varying function and A_o, A_i and B_i be the corresponding Fourier coefficients then:

$$z = A_o + \sum_{i=1}^{q} (A_i c_{it} + B_i s_{it})$$

where $c_{it} = \cos(2\pi it/N)$, $s_{it} = \sin(2\pi it/N)$

Over a time period U (where UN = one year) this function will have a cumulative value Z_T where:

$$Z_T = \int_{T-U}^{T} z\,dt = \int_{T-U}^{T} (A_o + \sum_{i=1}^{q} (A_i c_{it} + B_i s_{it}))dt$$

$$= A_o \int_{T-U}^{T} dt + \sum_{i=1}^{q} (A_i \int_{T-U}^{T} c_{it}dt + B_i \int_{T-U}^{T} s_{it}dt)$$

If we let T' = T - U/2 and U' = U/2 the terms $\int c_{it}$ and $\int s_{it}$ can be simplified.

$$\int_{T-U}^{T} c_{it}dt = \int_{T-U}^{T} \cos(2\pi it/N)dt$$

$$= [(N/2\pi i)\sin(2\pi it/N)]_{T-U}^{T}$$

$$= (N/2\pi i)(s_{iT} - s_{i(T-U)}) = (N/\pi i)c_{iT'}s_{iU'}$$

$$\int_{T-U}^{T} s_{it}dt = \int_{T-U}^{T} \sin(2\pi it/N)dt$$

$$= - \left[(N/2\pi i)\cos(2\pi it/N)\right]_{T-U}^{T}$$

$$= (N/2\pi i)(s_{i(T-U)} - s_{iT}) = (N/\pi i)s_{iT'}s_{iU'}$$

$$\therefore\ Z_T = A_oU + \sum_{i=1}^{q} (N/\pi i)s_{iU'}(A_i c_{iT'} + B_i s_{iT'})$$

To find estimates of A and B, let e_T be an error term such that:

$$y = \sum_{T=U}^{NU} e_T{}^2$$

$$= \sum_{T=U}^{NU} (Z_T - A_oU - \sum_{i=1}^{q} (N/\pi i)s_{iU'}(A_i c_{iT'} + B_i s_{iT'}))^2$$

y will be minimum when $\partial y/\partial A_o = 0$

$$\partial y/\partial A_o =$$

$$- 2U \sum_{T=U}^{NU} (Z_T - A_oU - \sum_{i=1}^{q} (N/\pi i)s_{iU'}(A_i c_{iT'} + B_i s_{iT'}))$$

$$\therefore\ \sum_{T=U}^{NU} Z_T =$$

$$\sum_{T=U}^{NU} A_oU + \sum_{i=1}^{q} (N/\pi i)s_{iU'}(A_i \sum_{T=U}^{NU} c_{iT'} + B_i \sum_{T=U}^{NU} s_{iT'})$$

$$\text{but } \sum_{T=U}^{NU} c_{iT'} = \sum_{T=U}^{NU} s_{iT'} = 0$$

$$\therefore\ A_o = (1/NU) \sum_{T=U}^{NU} Z_T$$

y will be minimum when $\partial y/\partial A_i = 0$

$\partial y/\partial A_i =$

$$-(N/\pi i)s_{iU'} \sum_{T=U}^{NU} c_{iT'}(Z_T - A_0U - \sum_{j=1}^{q} (N/\pi j)s_{jU'}(A_jc_{jT'}+B_js_{jT'}))$$

$= 0$

$$\therefore \sum_{T=U}^{NU} c_{iT'}Z_T = A_0U \sum_{T=U}^{NU} c_{iT'} +$$

$$\sum_{j=1}^{q} (N/\pi j)s_{jU'}(A_j \sum_{T=U}^{NU} c_{iT'}c_{jT'}+B_i \sum_{T=U}^{NU} c_{iT'}s_{jT'})$$

$$\text{but} \sum_{T=U}^{NU} c_{iT'}c_{jT'} = 0.5(\sum_{T=U}^{NU} c_{(i+j)T'} + \sum_{T=U}^{NU} c_{(i-j)T'})$$

$$= 0 \quad \text{for } \begin{matrix} i=1,q \\ j=i,q \\ i\neq j \end{matrix} \quad \text{and } NU/2 \text{ for } i=j$$

$$\sum_{T=U}^{NU} c_{iT'}s_{jT'} = 0.5(\sum_{T=U}^{NU} s_{(i+j)T'} - \sum_{T=U}^{NU} s_{(i-j)T'}) = 0$$

if we let $K_i = 2\pi i/N^2Us_{iU'}$

$$A_i = K_i \sum_{T=U}^{NU} c_{iT'}Z_T$$

y will be minimum when $\partial y/\partial B_i = 0$

$\partial y/\partial B_i =$

$$-(N/\pi i)s_{iU'} \sum_{T=U}^{NU} s_{iT'}(Z_T - A_0U - \sum_{j=1}^{q} (N/\pi j)s_{jU'}(A_jc_{jT'}+B_js_{jT'}))$$

$= 0$

$$\therefore \sum_{T=U}^{NU} s_{iT'}Z = A_0 U \sum_{T=U}^{NU} s_{iT'} +$$

$$\sum_{j=1}^{q} (N/\pi j) s_{jU'} (A_j \sum_{T=U}^{NU} s_{iT'}c_{jT'} + B_j \sum_{T=U}^{NU} s_{iT'}{}_{jT'}s)$$

$$\text{but } \sum_{T=U}^{NU} s_{iT'}c_{jT'} = 0.5(\sum_{T=U}^{NU} s_{(i+j)T'} + \sum_{T=U}^{NU} s_{(i-j)T'}) = 0$$

$$\sum_{T=U}^{NU} s_{iT'}s_{jT'} = 0.5(- \sum_{T=U}^{NU} c_{(i+j)T'} + \sum_{T=U}^{NU} c_{(i-j)T'})$$

$$= 0 \quad \text{for } \begin{array}{l} i=1,q \\ j=1,q \\ i \neq j \end{array} \quad \text{and } NU/2 \text{ for } i=j$$

$$\therefore \sum_{T=U}^{NU} s_{iT'}Z = (1/K_i)B_i$$

$$\therefore B_i = K_i \sum_{T=U}^{NU} s_{iT'}Z_T$$

The difference between the expressions for A_i and B_i and those found for a line passing through a set of points Z_T is the factor $\pi i/Us_{iU'}$.

A4.4 Calibration of Model

Introduction

The basic data for calibrating the model was taken from Rhys (1980) for the daily patterns for 1976/7 and from Energy Trends (Department of Energy, monthly) for quarterly electricity sales for 1973-1978. Estimates of off-peak domestic sales were obtained from a variety of sources and then substituted from total domestic to obtain on-peak domestic sales. Total traffic flow for 1976 was used as a surrogate for electric vehicle recharging.

Off-peak domestic seasonal variation

Seasonal variations in off-peak sales were assumed to be entirely due to changes in outside temperature leading to changes in off-peak heating requirements. It was assumed that off-peak sales vary in proportion to the difference between an inside temperature of 15.5°C and the outside temperature. Average monthly temperatures were taken from the Digest of United Kingdom Energy Statistics (Department of Energy annual). The degree-months ((15.5 - mean air temp)months) for 1973 to 1978, 1966/7 and 1976/7 are shown in Table A4.1.

Table A4.1 Degree Months

Year	Total	Quarter 1	2	3	4
1973	73.1	36.0	11.5	3.0	22.6
1974	73.2	37.8	10.7	0.2	24.5
1975	75.4	36.5	10.6	4.7	23.6
1976	76.3	35.8	14.6	4.9	21.0
1977	71.7	35.2	9.1	1.2	26.2
1978	70.1	32.9	8.4	2.1	26.7
66/7	75.0				
76/7	75.7				

According to Platts (1978) the average off-peak sales to all Domestic consumers was 250 kWh/consumer in 1966/7 and 760 kWh/consumer in 1976/7. This was used to find average sales per consumer per degree-months for both these years then linear interpolations of sales per consumer per degree-month were made for the years 1973 to 1978. These were used in conjunction with the degree-months in Table A4.1 to obtain the estimates of domestic off-peak sales shown in Table A4.2.
The number of consumers was taken from Department of Energy (annual).

Table A4.2 Off-peak Domestic Sales

Year	'000 Av Consumers	Off-peak per consumer MWh	Off-peak sales Total	Quarter 1	2	3	4 GWh
1973	19222	0.575	11044	5439	1737	453	3415
1974	19430	0.624	12133	6265	1774	33	4061
1975	19691	0.694	13661	6613	1921	852	4276
1976	19948	0.753	15025	7050	2875	965	4135
1977	20222	0.756	15286	7504	1940	256	5586
1978	20483	0.786	16101	7556	1929	482	6132

Seasonal variation for all sectors

Sales to each sector in each quarter are shown in Table A4.3.
The above estimates of off-peak sales to the domestic sector were used to split the domestic sales into on- and off-peak. To allow for the growth in sales which took place between 1973 and 1978 a two by four moving average [1] of quarterly sales was found and this was used to scale each quarters sales. The averages of these scaled sales were then found. The resultant fourier series coefficients are shown in Table A4.4.
The fourier series for off-peak domestic is such that it gives very small (smaller than -0.05) negative values during July. Within the computer programme these negative values are taken to be zero.

The seasonal variation for electric vehicle battery recharging was assumed to be proportional to the seasonal traffic flows. 1976 total traffic (Department of Transport annual a) was used to estimate the fourier series coefficients as shown in Table A4.5.

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[1] The average of four quarters data gives a value which is central about a point half way between the centre two quarters. To get a value which is actually centred on a quarter the mean of two adjacent four quarter averages can be taken. This is known as a two by four moving average. For example if 73q1 represents the value of the quantity being averaged, in the 1st quarter of 1973, then the two by four moving average for the 3rd quarter of 1973 is:

(73q1/2 + 73q2 + 73q3 + 73q4 + 74q1/2) / 4

Table A4.3 Quarterly Electricity Sales

Year	q	Domestic Act'l	Av.	*100 A/Av	Com & Ser Act'l	Av.	*100 A/Av	Industry Act'l	Av.	*100 A/Av	D Off-peak Act'l	Av.	*100 A/Av
1973	1	24592			13820			22774			5439		
	2	18419			10672			21688			1737		
	3	14435	19989	72	9315	11751	79	20315	21679	94	453	2864	16
	4	22809	19846	115	13188	11743	112	22196	21508	103	3415	2972	115
1974	1	23999	19934	120	12839	11731	118	22260	21389	104	6265	2924	214
	2	17863	20091	89	10585	11794	90	20833	21427	97	1774	2952	60
	3	15693	20064	78	9313	11858	79	20222	21411	94	33	3077	1
	4	22811	20045	114	13687	11850	116	22587	21237	106	4061	3139	129
1975	1	23776	19760	120	13858	11824	117	21746	20928	104	6613	3259	203
	2	17934	19143	94	10497	11748	89	19957	20624	97	1921	3388	57
	3	13342	18602	72	9193	11752	78	18622	20648	90	852	3470	25
	4	20224	17927	113	13199	11806	112	21755	20903	104	4276	3644	117
1976	1	22039	17379	127	14379	11813	122	22767	21227	107	7050	3777	187
	2	14273	17406	82	10408	11932	87	20981	21661	97	2875	3744	76
	3	12619	17400	73	9339	12096	77	20189	22019	92	965	3813	25
	4	21161	17602	120	14005	12319	114	23656	22272	106	4135	3753	110
1977	1	21060	18183	116	14886	12616	118	23731	22470	106	7504	3548	212
	2	16863	18048	93	11685	12737	92	22047	22376	99	1940	3640	53
	3	14682	17610	83	10435	12810	81	20704	22235	93	256	3828	7
	4	18011	17546	103	13876	12957	107	22389	22320	100	5586	3833	146
1978	1	20710	17525	118	15599	13082	119	23867	22429	106	7556	3860	196
	2	16698	17475	96	12152	13263	92	22595	22597	100	1929	3957	49
	3	14684			10971			21026			482		
	4	17611			14784			23414			6132		
Av	1			120.303			118.824			105.451			202.220
of	2			90.717			89.940			97.875			58.998
A/	3			75.609			78.940			92.630			14.686
Av	4			112.883			112.078			104.030			123.505

Table A4.4 Fourier Series Coefficients

Sector	A_1	B_1	B_2
Domestic on-peak	0.2929	0.0886	-0.0302
Commercial & Service	0.2437	0.0697	-0.0167
Industry	0.0745	0.0262	-0.0150
Domestic off-peak	0.9912	0.4838	0.1353

Table A4.5 Fourier coefficients for Electric vehicle battery recharging

1976 Total traffic million vehicle km

month	1	2	3	4	5	6
traffic	17878	17466	20168	20082	22238	22520
month	7	8	9	10	11	12
traffic	24340	24785	23083	21086	19786	18004

Fourier coefficients

i	1	2	3	4	5	6
A_i	-0.1449	-0.0121	0.0044	-0.0067	0.0240	
B_i	-0.0622	0.0176	-0.0181	-0.0032	0.0059	0.022

Daily load patterns

The results of the Electricity Council's grid load curve analysis of a mid winter mid week day (at 32°F) and for a midweek Summer day (at 72° F), for 1976-77 are shown in Figures A4.2 to A4.4.

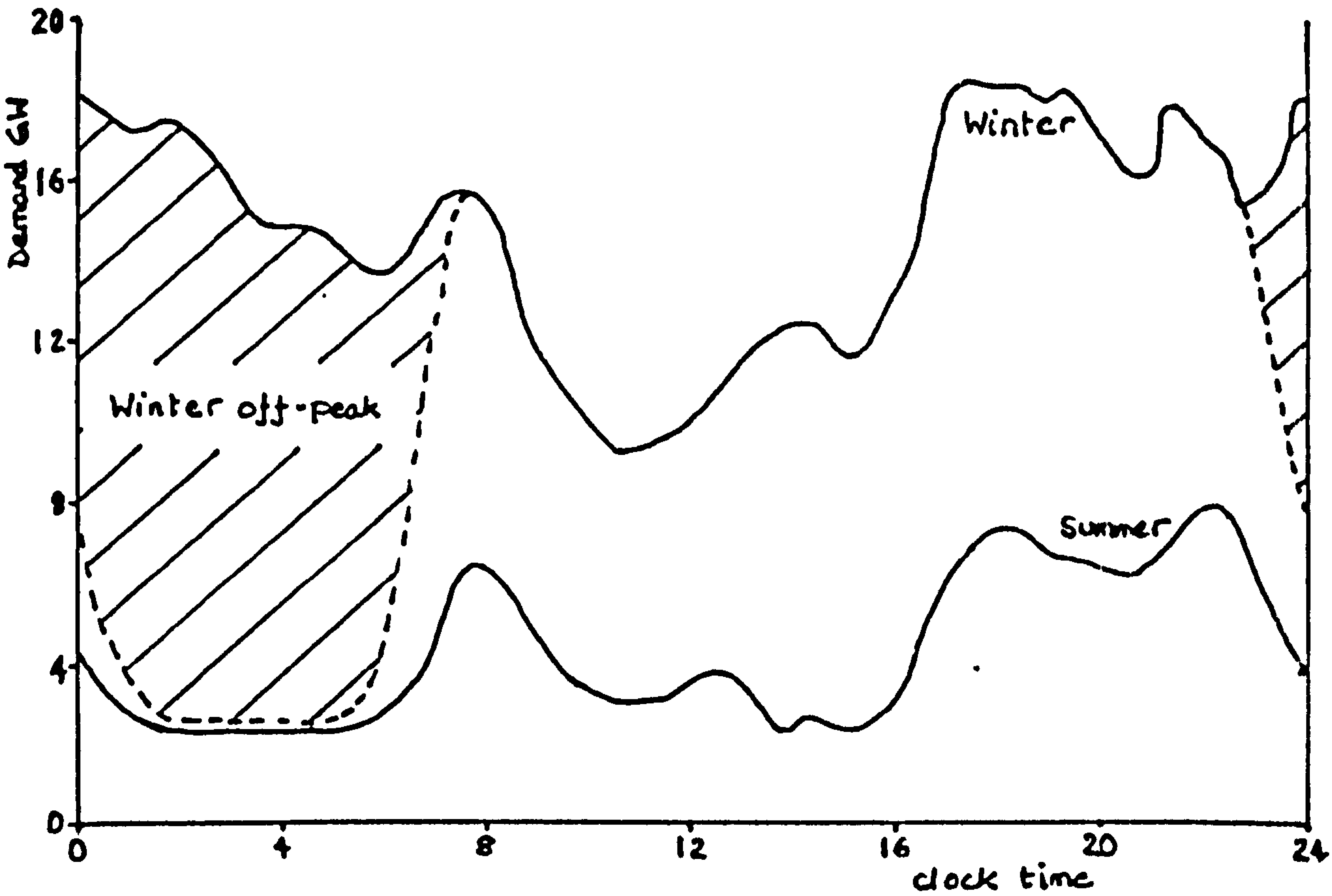

Figure A4.2 1976/7 Summer and Winter Domestic load patterns

Also shown in Figure A4.2 is my estimate of the off-peak component of the

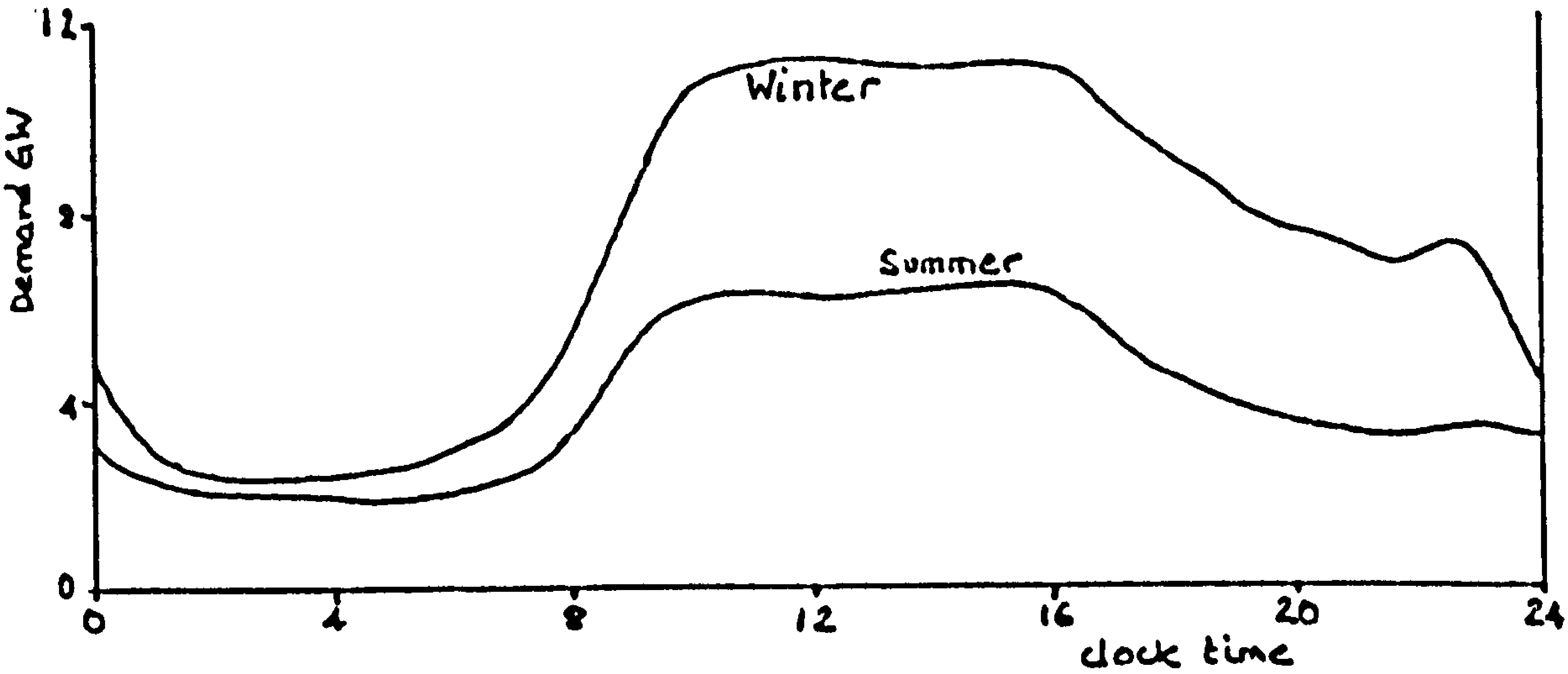

Figure A4.3 1976/7 Summer and Winter Commercial load patterns

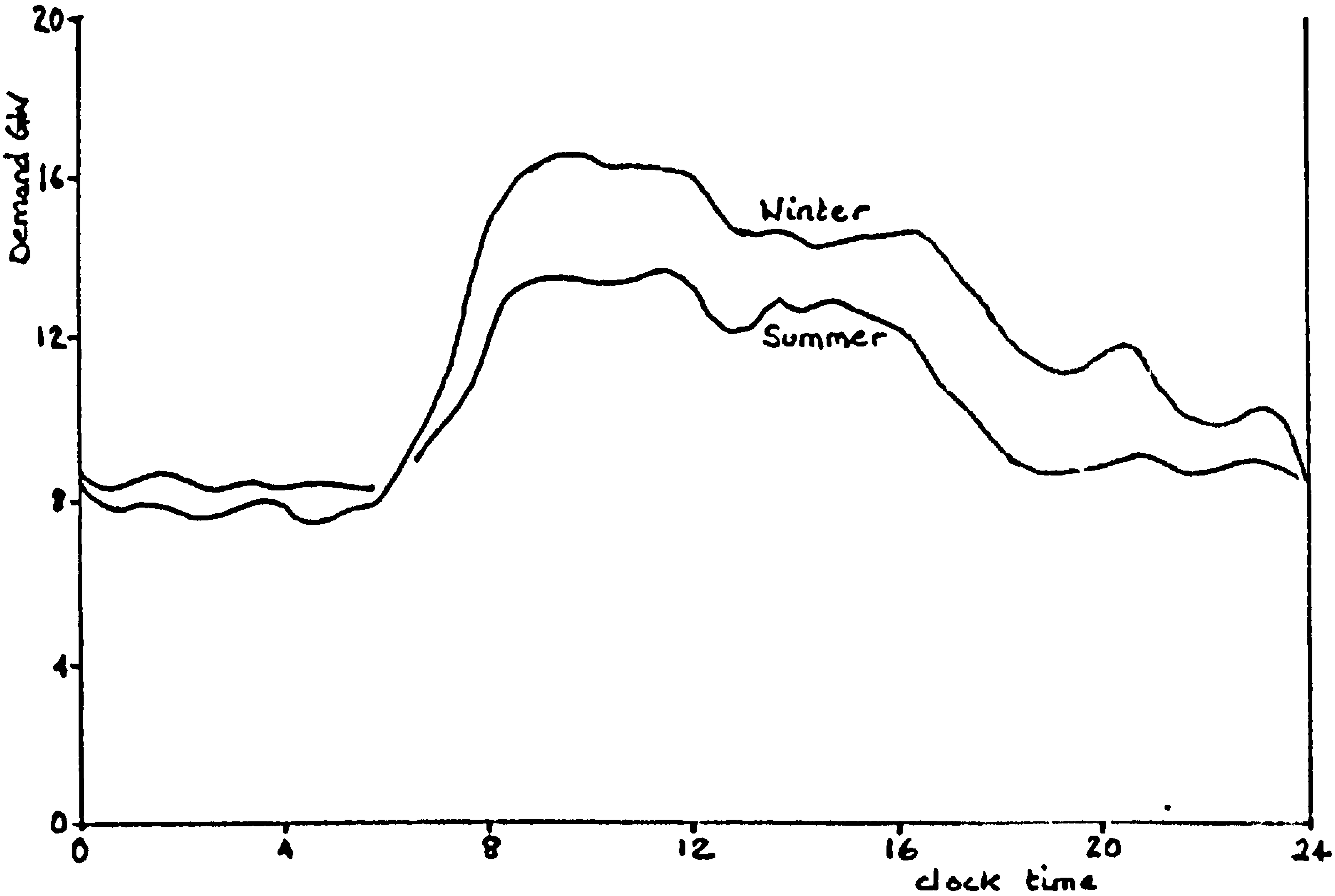

Figure A4.4 1976/7 Summer and Winter Industrial load patterns

domestic load pattern. The size of the off-peak domestic component was adjusted so that it has a minimum equal to the summer night time minimum, it starts at 2300, it ends at 0700 and has an area equal to that estimated using the seasonal pattern found above and total off-peak sales for 1976-77 from above.

The load patterns for the model were obtained by dividing the actual loads for each half hour by the sectors average load for the day. The domestic winter off-peak pattern was also used for the domestic summer off-peak pattern and both electric vehicle patterns. However it should be remembered that the model also used "logic loads" for these off-peak shapes as well (see above Section A4.2).

A4.5 Validation

The only validation of the model has been to compare load duration curves as estimated for 1973/4 to 1977/8 with actual load duration curves for these years. Unfortunately the average loads used in the model, taken form Table A4.3 were for Great Britain, whereas the actual load curves were for the CEGB. The actual and estimated load duration curves are shown in Figures A4.5 to A4.9.

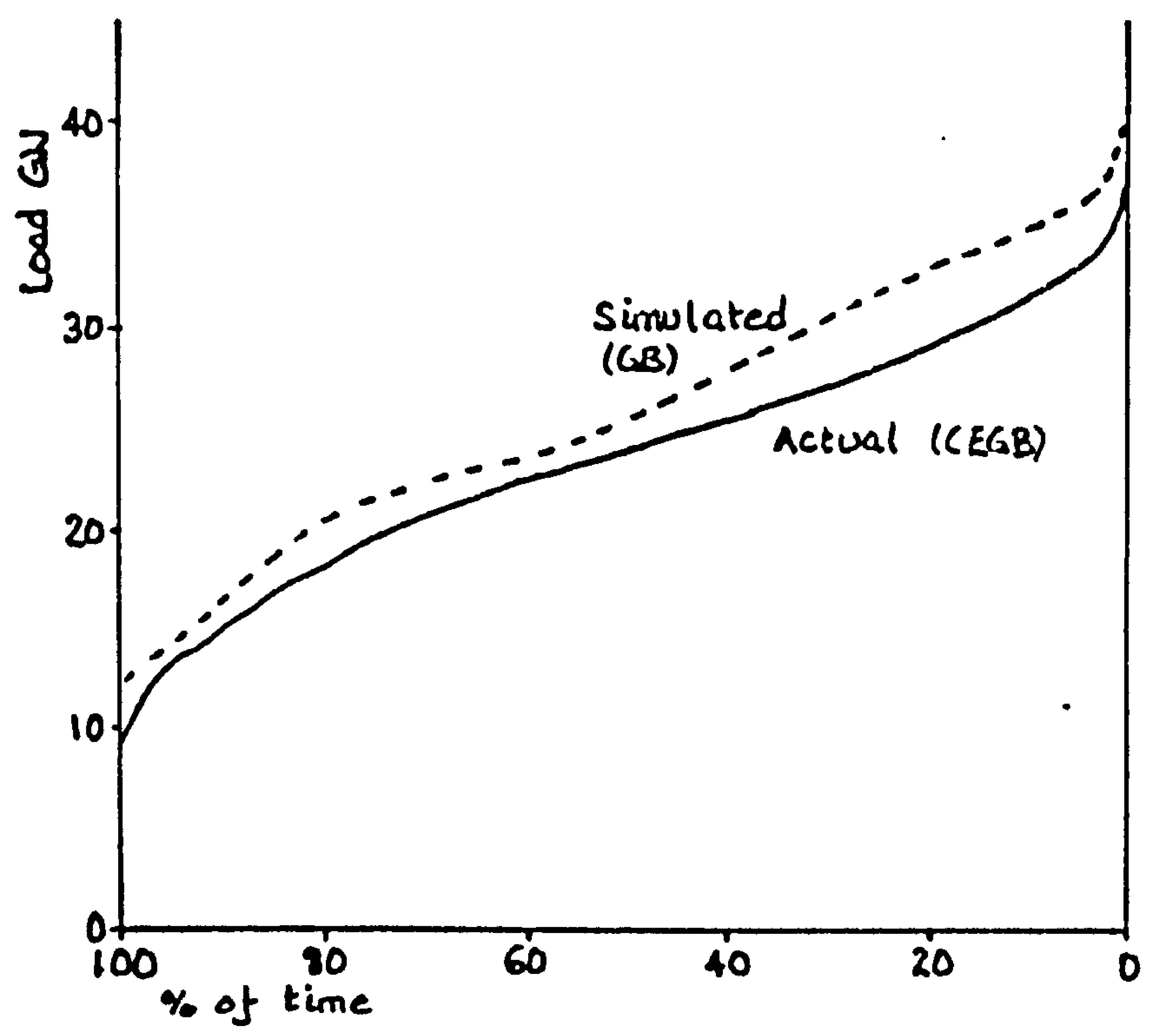

Figure A4.5 1973/4 Actual and simulated load duration curves

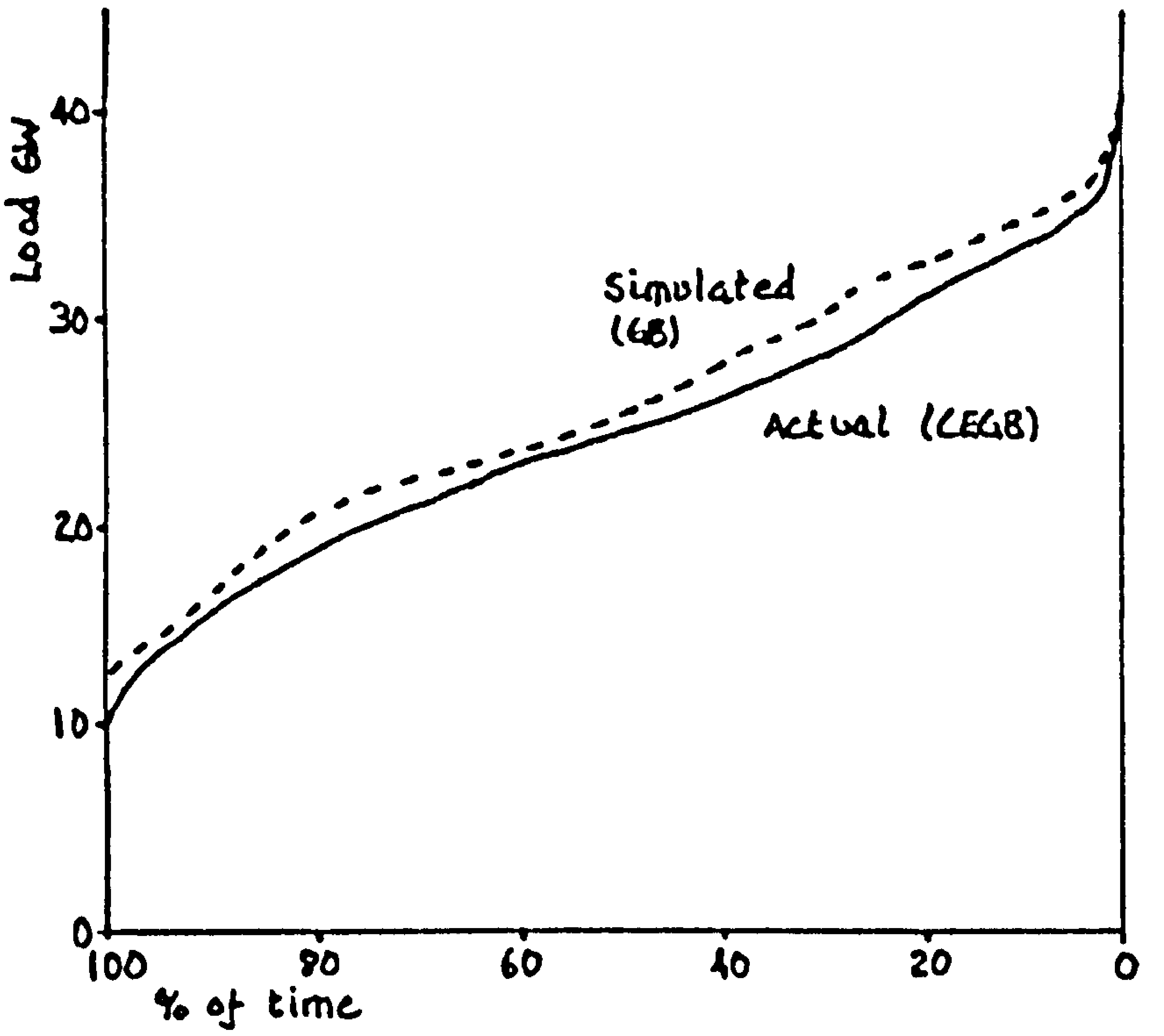

Figure A4.6 1974/5 Actual and simulated load duration curves

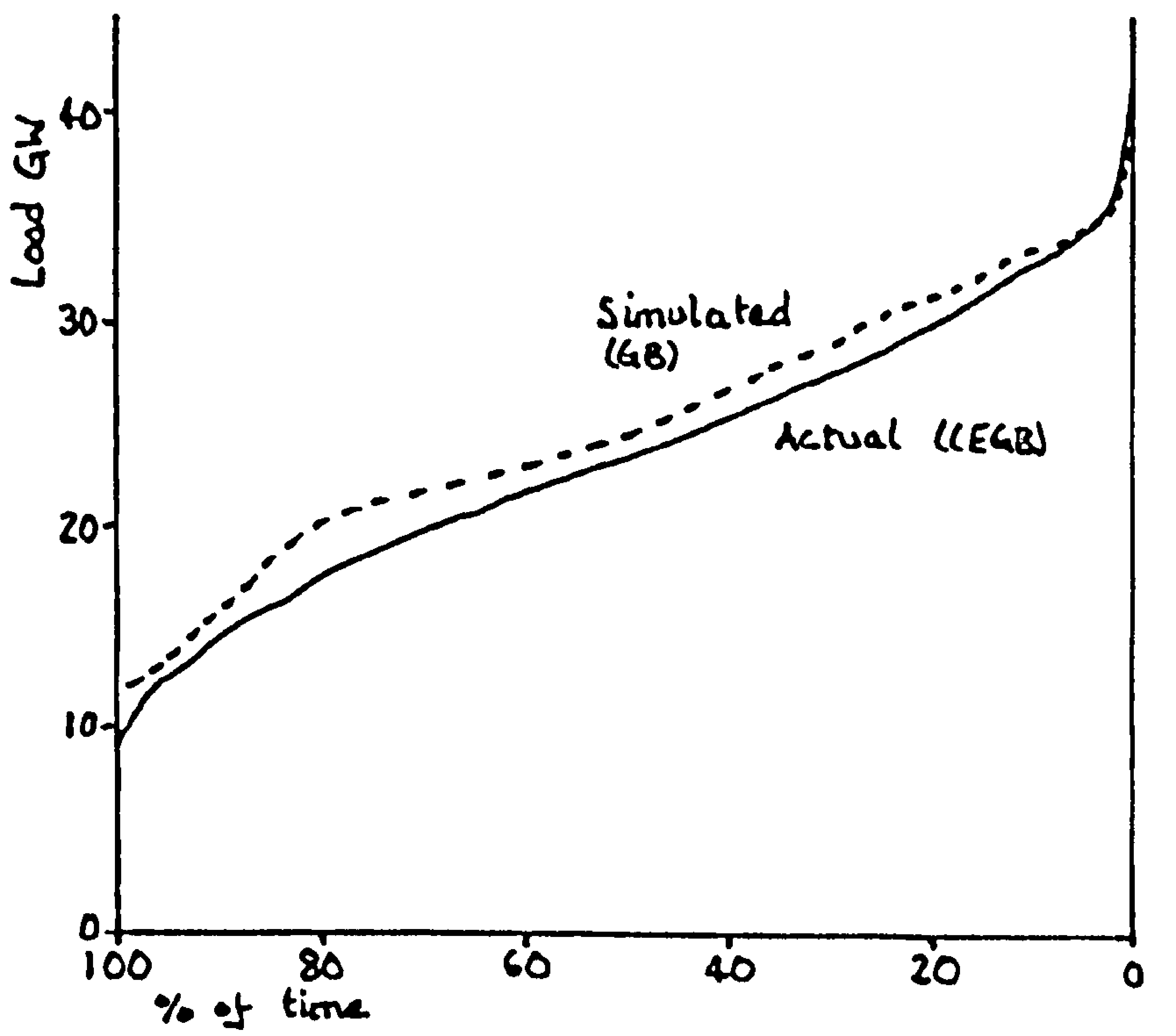

Figure A4.7 1975/6 Actual and simulated load duration curves

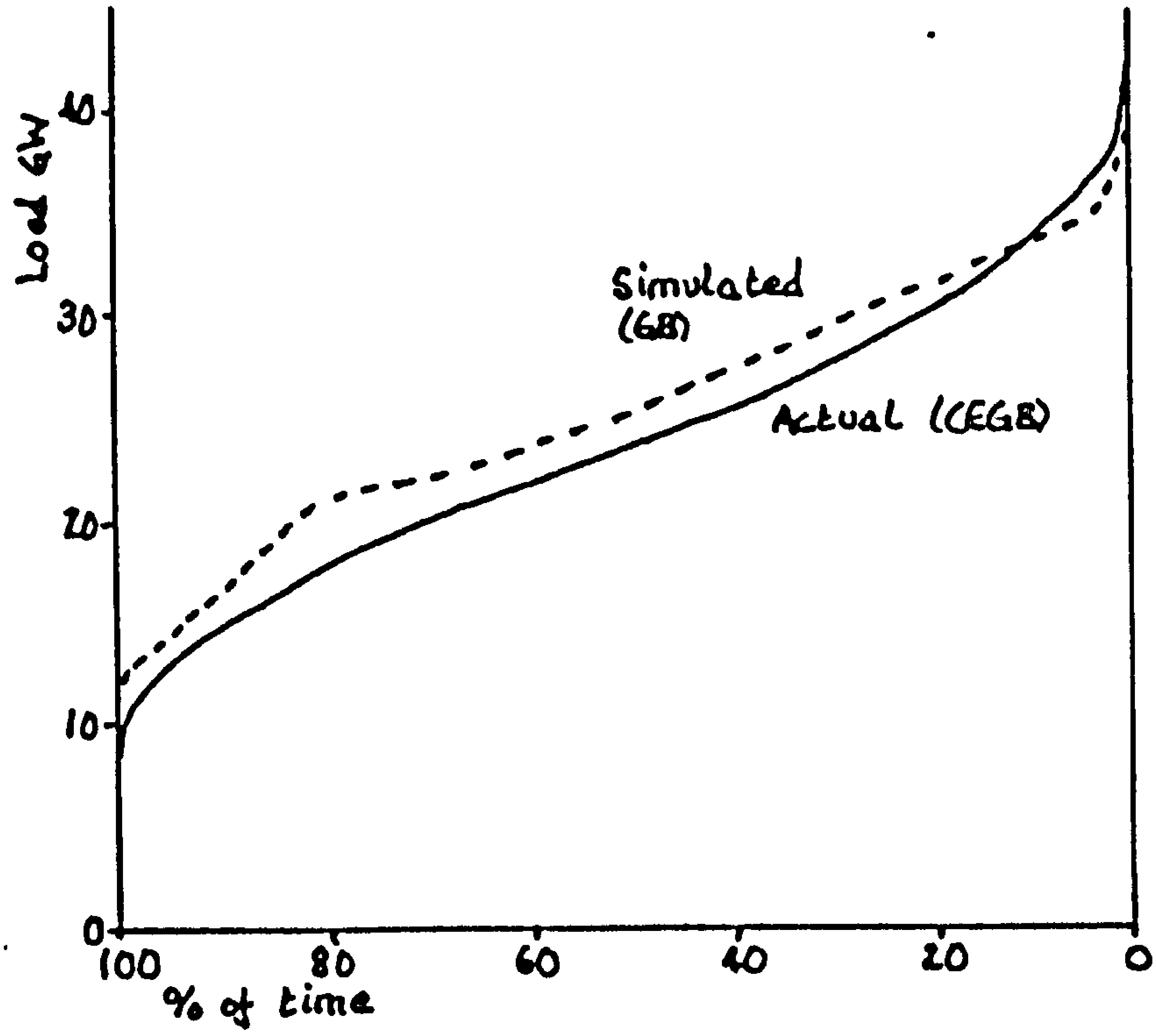

Figure A4.8 1976/7 Actual and simulated load duration curves

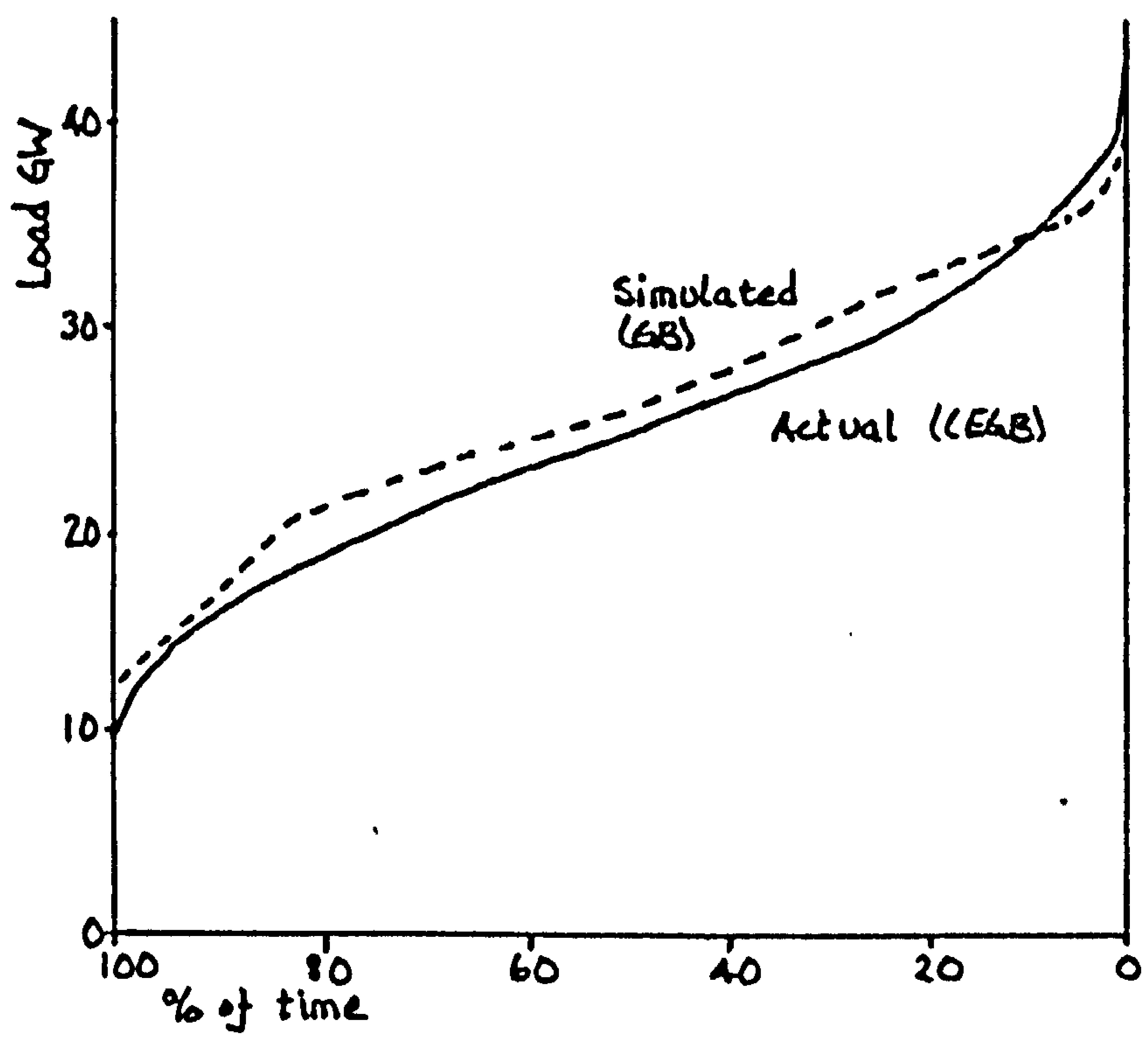

Figure A4.9 1977/8 Actual and simulated load duration curves

A4.6 Comments on the Model

Assumptions

In the construction of the half hourly electricity demand model several assumptions were made. These are briefly listed below.

The first assumption is that the half hourly patterns of electricity demand for each sector remain constant over time. However from the Electricity Council's grid load curve analysis it is known that this is not true. Such an assumption would require an unchanging mix of uses within each sector, which for the domestic, sector would also mean no changes in lifestyle.

It is also assumed that the fourier series is a reasonable approximation to the seasonal variations in demand and that a sinusoidal weighting of summer and winter patterns will produce a reasonable approximation to the daily pattern at other times of year.

Short comings

One of the main short comings of the model structure is that it does not allow for variations in demand due to such factors as the weather other than annual seasonal variations. Random fluctuations in weather are not accounted for. Another short coming of the current version of the model is that it has had very little validation. Also no account was taken of off-peak sales to the commercial sector. Although data was available on the sales of off-peak to the commercial sector in the same amount of detail as for the domestic sector no satisfactory way could be found for estimating the daily commercial off-peak load pattern.

APPENDIX 5. CORRESPONDENCE WITH THE CENTRAL STATISTICAL OFFICE

This Appendix consists of two letters from CSO and a reply from me. The letter from Fred Johnson and my reply were both accompanied by tables of estimates of the output of, and inputs to, road haulage. These were my first and second sets of estimates. For comparison I have also included the final set of estimates which appeared in Baker (1979a).

CABINET OFFICE

Central Statistical Office

Great George Street, London SW1P 3AQ Telephone 01-233 -7693

Our ref: D2/22 22 March 1979

Dear Mike

ROAD HAULAGE 1974

There has been some discussion between the CSO and the Department of the Environment about the appropriate weight to be given to the road haulage indus (excluding own account) in the index of GDP(O). The weight is based on the gross value added in the industry in 1975 and the main problem is over the siz of the profits component of value added.

The national accounts derive their estimates of value added from inland revenu returns and these show considerably lower profits than those implied from othe sources - including the estimates of input and output of road haulage which yo prepared for the 1974 input/output tables. Table 5 of your first report (copy attached) shows total output of £2436m and total inputs (including labour costs of £1693m thus giving a residual profit figure of £743m. This is about twice large as the revenue estimate.

What I would like to ask is whether you have any views on the reliability of your estimates. I realise that they are based largely on the Commercial Motor tables of operating costs and to that extent simply mirror the soundness of th tables. But do you know of any other sources which might provide an alternati estimate of profitability in road haulage?

I am sorry to drag you into what is essentially an internal problem but now th you are a world expert on UK transport statistics could we ask for some free advice? I am copying this to Keith Childs in the GDP(O) section here and Mike Haslam at DoE.

Yours sincerely

Fred

F J JOHNSON

Mr M Baker
Energy Research Group
Open University
Walton Hall
Milton Keynes
Bedfordshire

Enc

Table A5.1 shows my 1st round estimates on road haulage and was enclosed with Fred Johnsons letter of 22 March 1979 (see previous page).

Table A5.1 Road Haulage 1974 (1st estimates)

Output £ million

I.O. No.(s)	Commodity	Total
94(703)	Road Haulage	2 435.7

Physical Output

I.O. No.(s)	Commodity	Total
94(703)	Road Haulage (million tonnes)	731.4
	(million tonne km)	49.210

Input £ million

I.O. No.(s)	Commodity	Total
5,6,7,11,59 85,95,102	Overheads	114.4
11	Fuel	261.0
	Lubricants	11.6
59	Spare parts	88.9
?	Other materials for vehicles	13.0
89	Tyres	76.5
99	Vehicle insurance	94.0
	Other insurance	20.5
100,0	Rent and rates	39.9
102	Amounts paid out for maintenance and repairs	66.2
0	Salaries, wages, N.I. and grad. pension	848.7
0	Licences	58.5
	Total	1 693.2

Physical Input

I.O. No.(s)	Commodity	Total
11	Fuel ('000 gallons)	561.100

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Our Ref. MB/PC
Your Ref.

THE OPEN UNIVERSITY

F. J. Johnson
Central Statistical Office
Great George Street
London SW1P 3AQ

27 March 1979

Dear Fred,

Thank you for your letter of 22 March and for conferring World Status, frankly I feel woefully ill informed. I am enclosing my (hopefully) final results for Road Haulage. These are based on the work I came to discuss with you about a month ago.

I am assuming that all public haulage in Order XXII is performed by Road Haulage, MLH 703. It is probably not but I suspect the difference is within the level of accuracy of the estimates. You will see that the Gross Profit is now £449m (considerably less than the previous £743m).

I have made certain changes to my methods which you will be able to see when I have finished writing up the road transport work. Basically, I have reduced the Rent and Rates and Interest unit costs to 0.2 of the Commercial Motor Table valves and Insurance to 0.6 of the CM valves. This is to keep the figures more in line with the results quoted in Edward + Bayliss, Operating Costs in Road Freight Transport. I have also altered the method of calculating Overheads and Profit which CM take as 20% of all other costs, for both. I am now taking 7.87% and 0% respectively for own account operation and 18.08% and 23.16% for public haulage which are again in line with Edward + Bayliss. If the revenue estimate is similar to my own this would be a great comfort as the Edward + Bayliss figures are for 1965!

I hope this may be of some help.

Yours sincerely,

Mike Baker

Mike Baker

Encs:

Table A5.2 shows my 2nd round estimates on road haulage and was enclosed with my letter of 27 March 1979 (see previous page).

Table A5.2 Road Haulage 1974 (2nd estimates)

Output £ million

I.O. No.(s)	Commodity	Total
94(703)	Road Haulage	~~2 435.7~~ 1614.8

Physical Output

I.O. No.(s)	Commodity	Total
94(703)	Road Haulage (million tonnes)	~~731.4~~
	(million tonne km)	~~49.210~~

Input £ million

I.O. No.(s)	Commodity	Total
5,6,7,11,59 85,95,102	Overheads	~~114.4~~ 73.5
11	Fuel	~~261.0~~ } 277.0
	Lubricants	~~11.6~~
59	Spare parts	~~88.9~~ 96.5
?	Other materials for vehicles	~~13.0~~ 5.6
89	Tyres	~~26.5~~ 74.0
99	Vehicle insurance	~~94.0~~ } 60.7
	Other insurance	~~20.5~~
100,0	~~Rent and rates~~ Hiring Vehicles	~~38.9~~ 25.1
102	Amounts paid out for maintenance and repairs	~~66.2~~ 28.9
0	Salaries, wages, N.I. and grad. pension	~~848.7~~ 470.0
0	~~Licences~~ Taxes	~~58.5~~ 55.0
	Gross profit	448.6 } 973.6
	Total	~~1 693.2~~ 1614.8

Value added is 60.3 %

Physical Input

I.O. No.(s)	Commodity	Total
11	Fuel ('000 gallons)	~~561.100~~

Table A5.3 shows my final estimates on road haulage which appeared in Baker (1979a).

Table A5.3 Road Haulage 1974 (final estimates)

Output £ million

I O No.(s)	Commodity	Total
94(703)	Road Haulage	1537.7

Physical Output

I O No.(s)	Commodity	Total
94(703)	Road Haulage (million tonnes) (million tonne km)	673.3 52246

Input £ million

I O No.(s)	Commodity	Total
5,6,7,11,59 85,95,102	Overheads	70.0
11	Fuel and lubricants	285.7
59	Spare parts	94.7
?	Other materials for vehicles	5.5
89	Tyres	74.0
94(703)	Hiring vehicles	22.2
99	Insurance	54.7
102	Amounts paid out for maintenance and repairs	28.3
0	Salaries, wages, NI and grad. pension	419.2
0	Taxes	48.7
0	Gross profit	434.8
	Total	1537.7

Physical Input

I O No.(s)	Commodity	Total
11	Fuel ('000 tonnes)	2280

CABINET OFFICE

Central Statistical Office

Great George Street, London SW1P 3AQ Telephone 01-233 7350

Our Ref: D2/22/H01514

2 May 1979

Dear Mr Baker

TRANSPORT SECTOR INPUT-OUTPUT 1974

I have just seen, in manuscript, your final input-output reports for the transport industries for 1974.

Various parts of your report, in its earlier stages, have already been incorporated in our tables on a provisional basis. I have no doubt that in a work of this size there will be a number of points needing clarification and further discussion, and we may of course need to modify your results in some respects when we have completed our look at the input-output results as a whole. It is perhaps too early yet to make a final assessment of the value of your work.

But on the basis of what has been looked into so far, it is clear that it does represent a major improvement in the methods of arriving at reliable estimates of the transactions of the transport industries and in the quality of the results obtained.

I must congratulate you on the thoroughness and care that have obviously been taken to arrive at these very comprehensive results. I am sure your report and methods used will be a model for preparing similar estimates for the transport sector for future years.

I am sending copies of this letter to Dr G Alexander, Head of the Energy Research Group and to Mr T R Walsh of the Transport and Road Research Laboratory.

Yours sincerely

M J G Lockyer

M J G LOCKYER
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